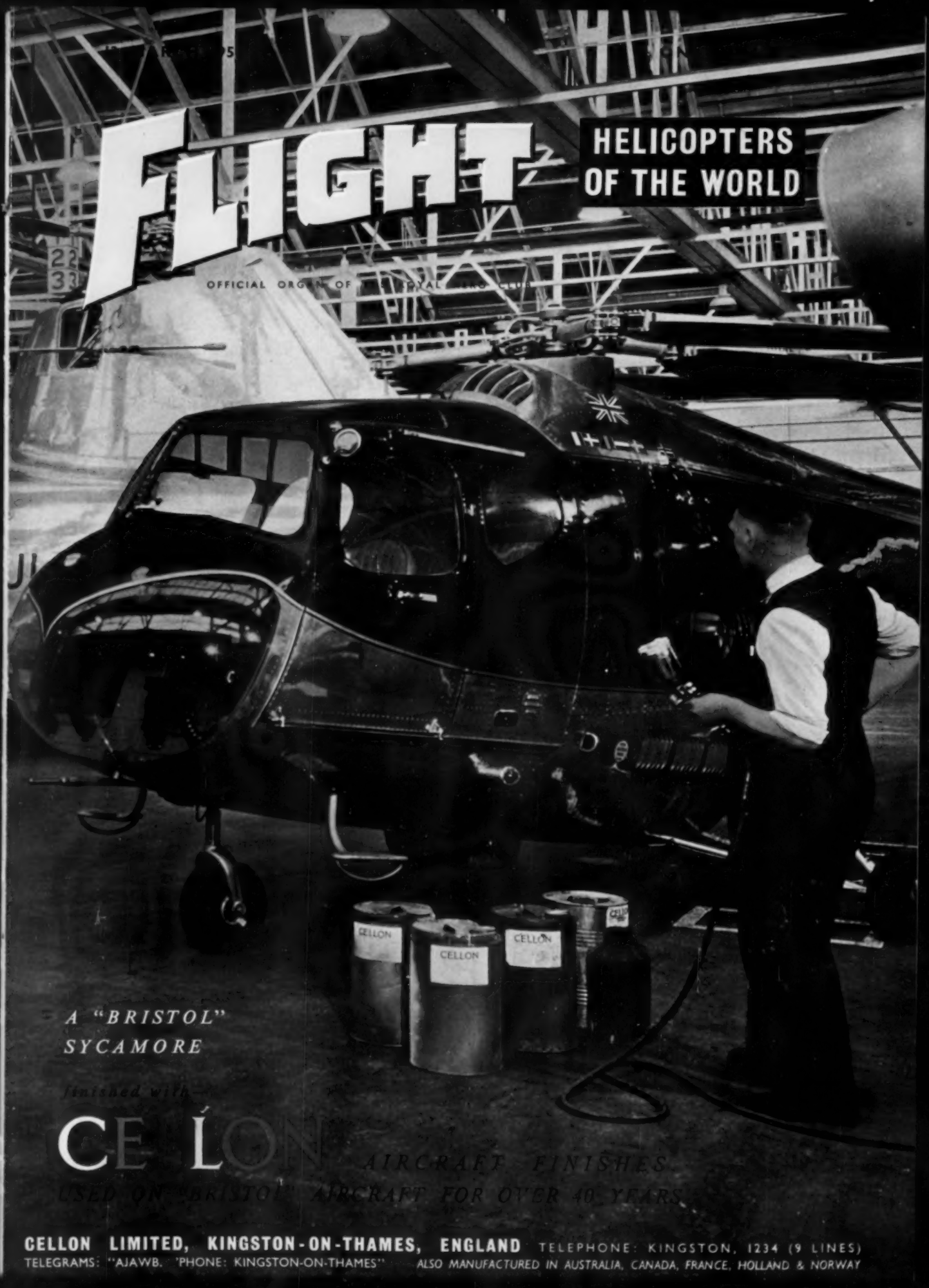
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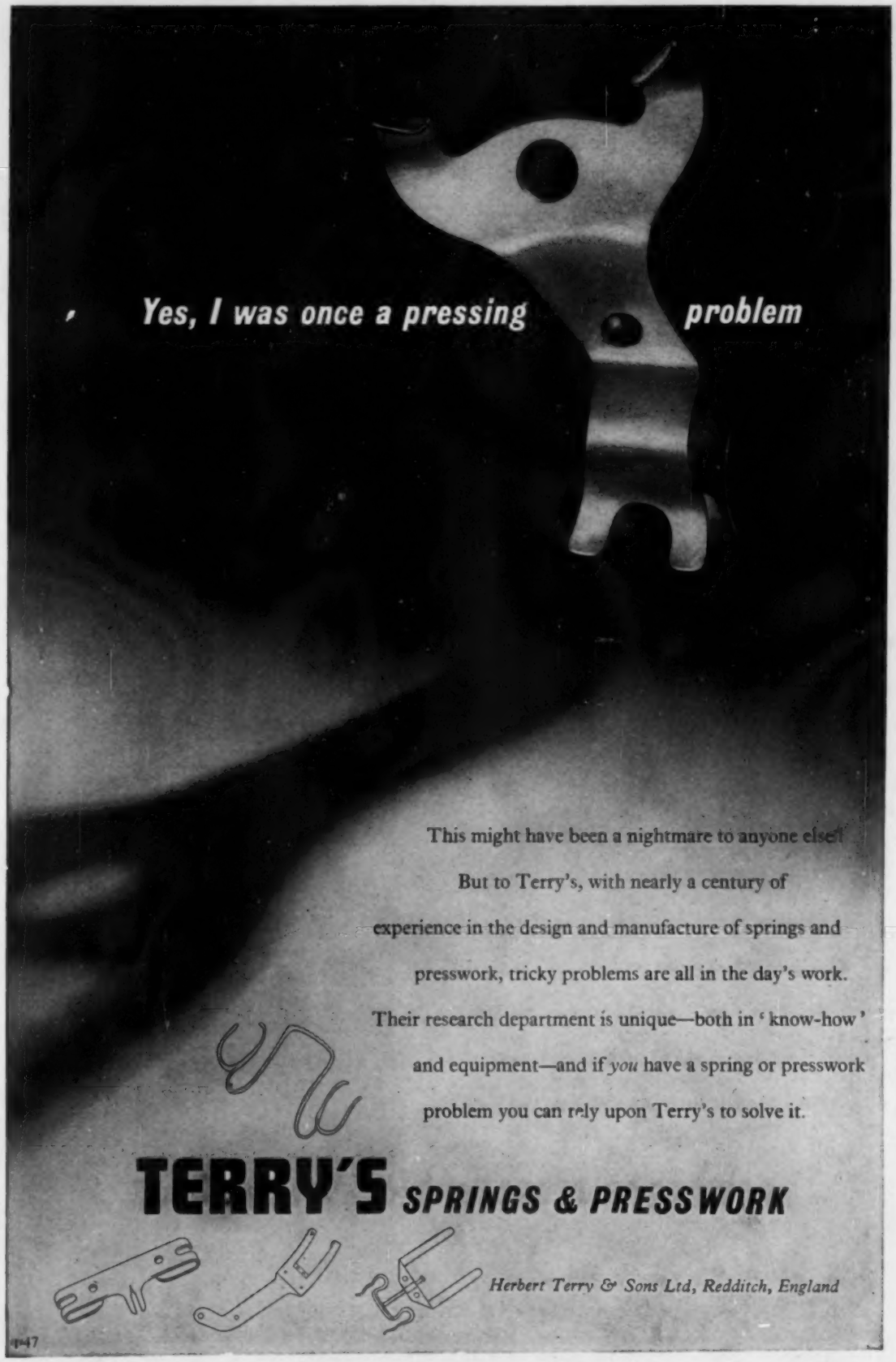
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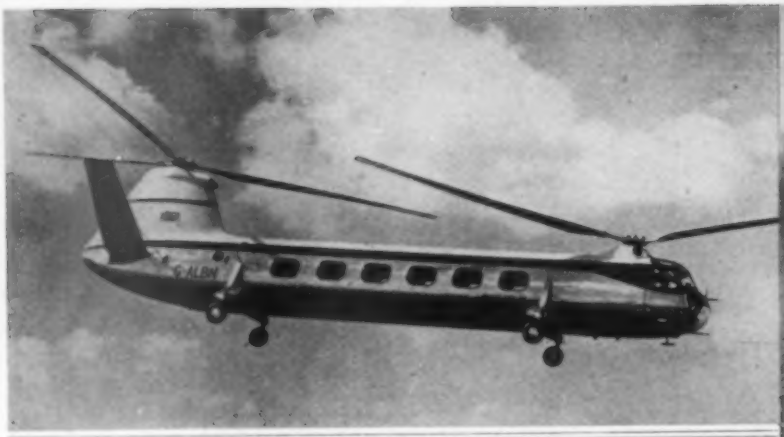

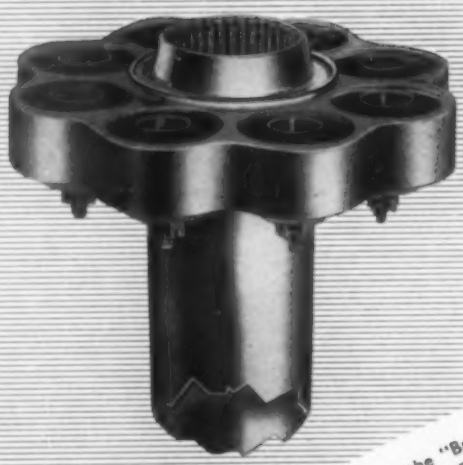

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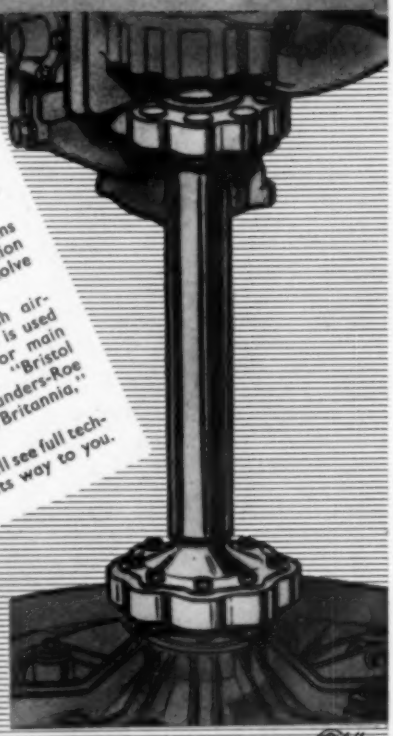

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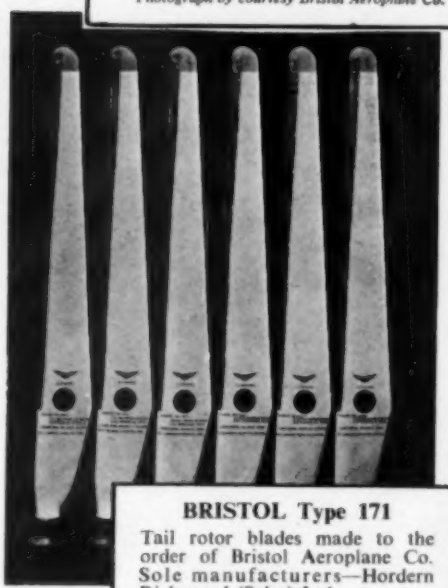
Photograph by courtesy Bristol Aeroplane Co.

WESTLAND S.51
Tail rotor blades manufactured in accordance with the U.S. design and specification to the order of Westland Aircraft Ltd. Sole manufacturers—Hordern Richmond (Sales) Ltd.
Photograph by courtesy Westland Aircraft.



BRISTOL Type 171
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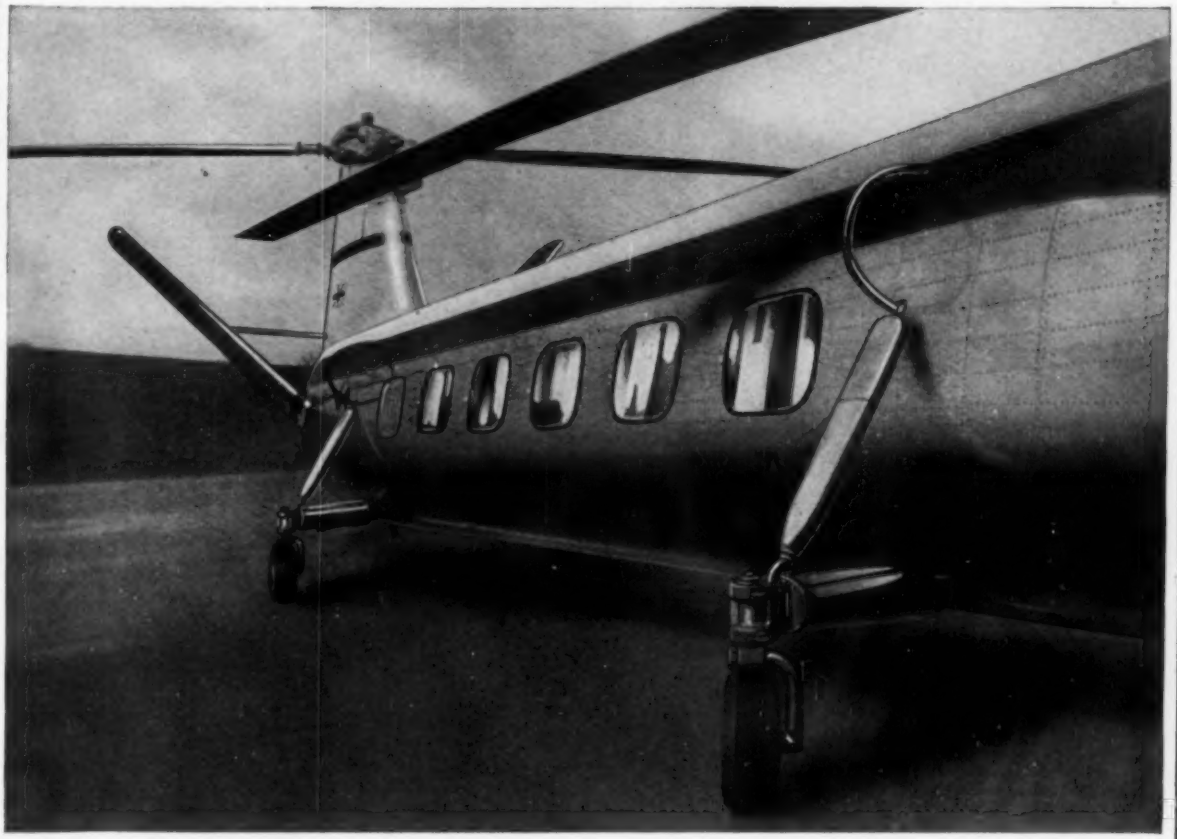

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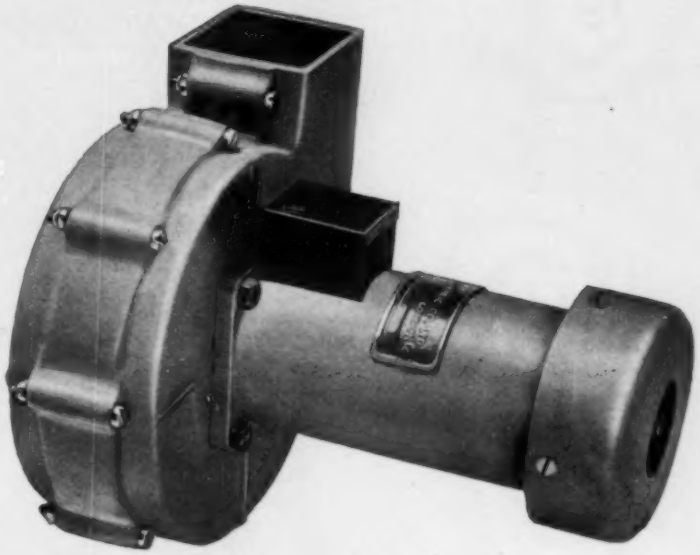

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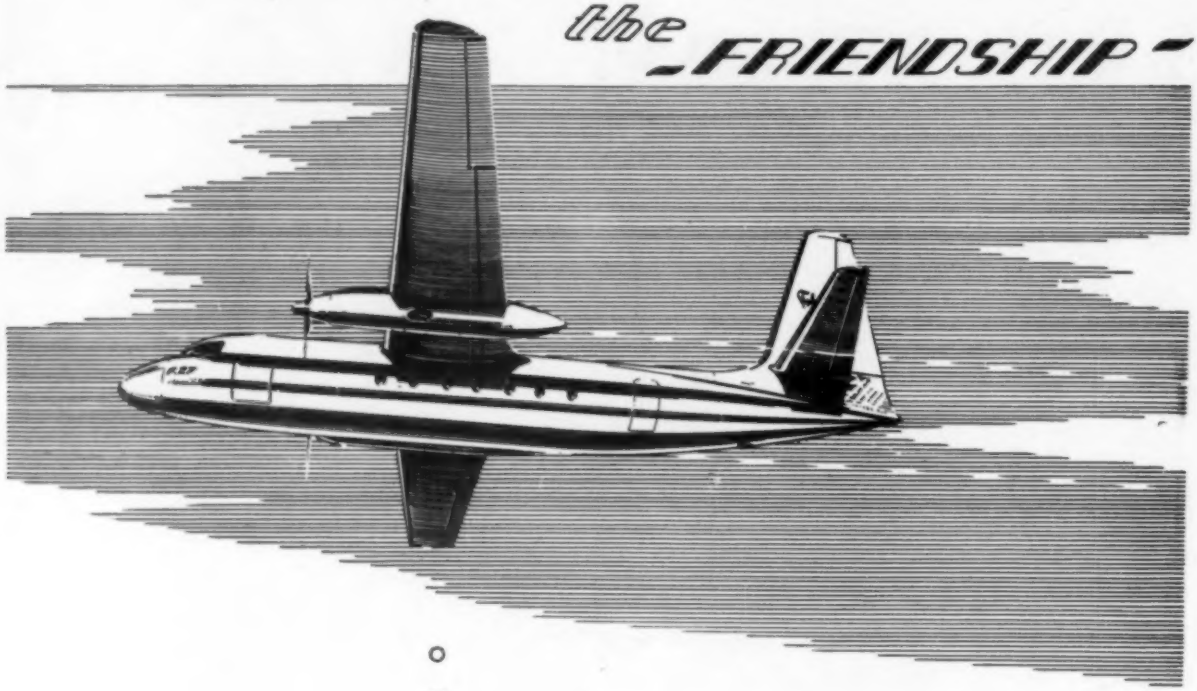

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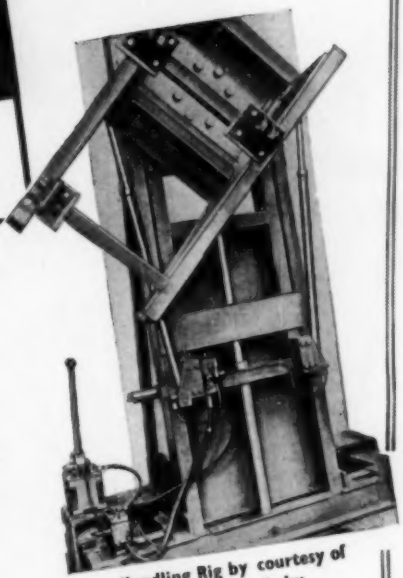

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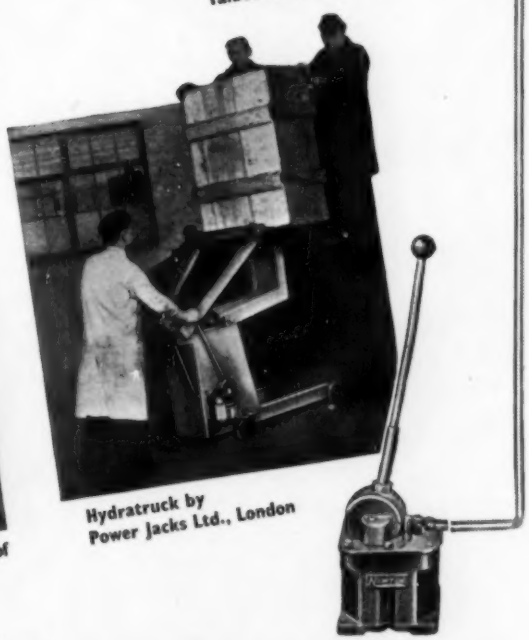

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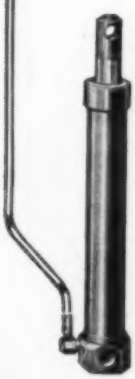

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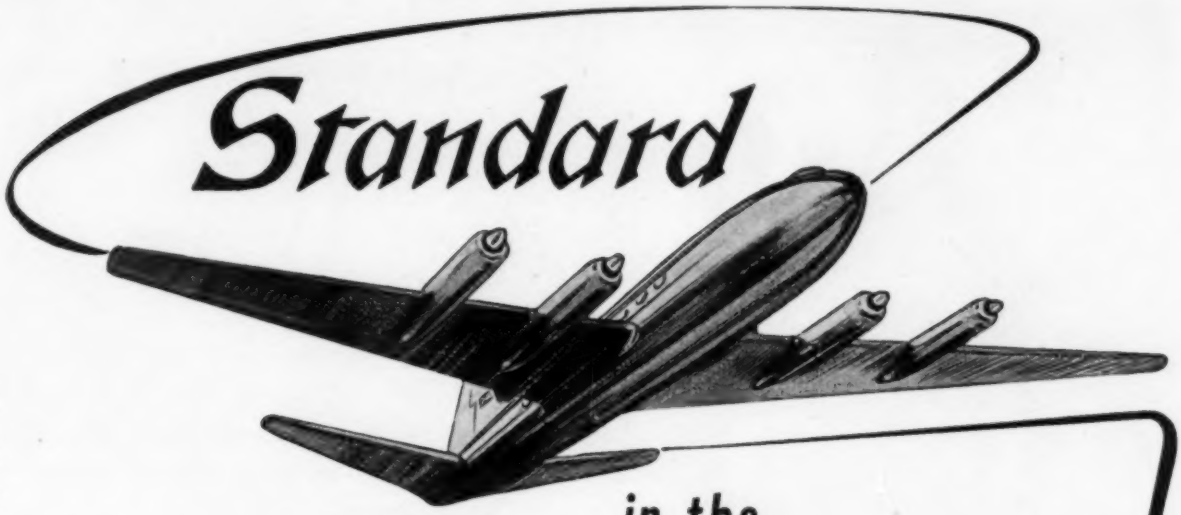

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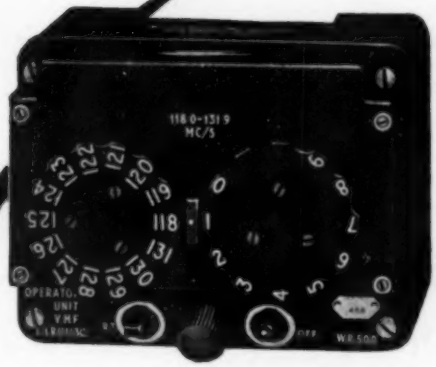

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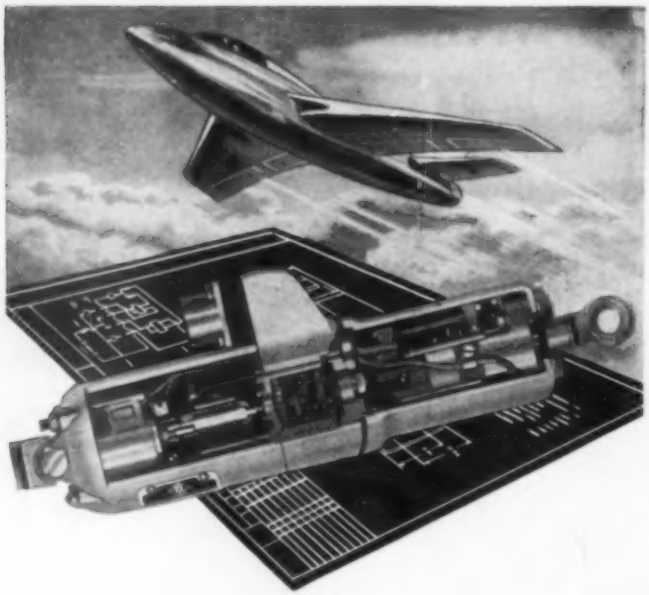

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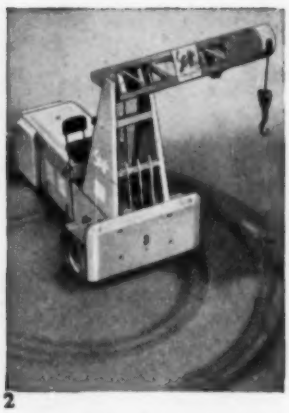

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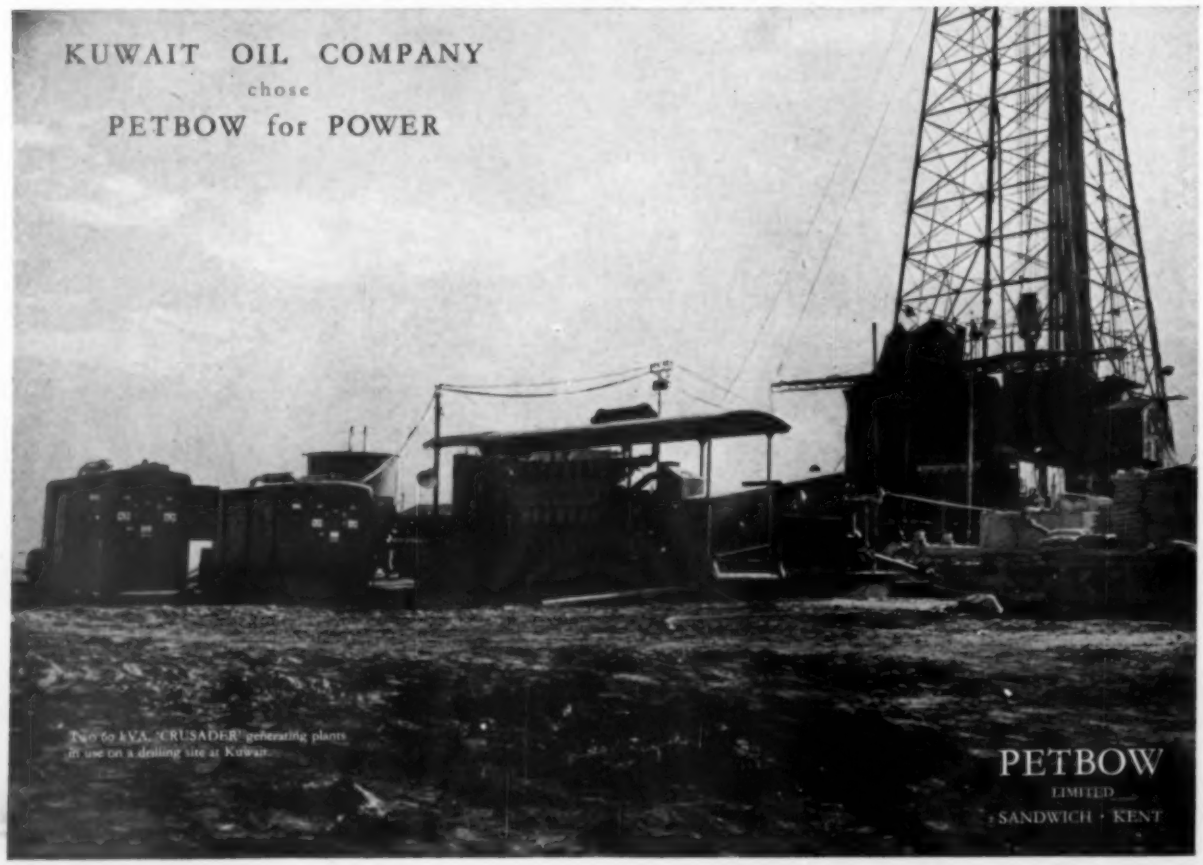

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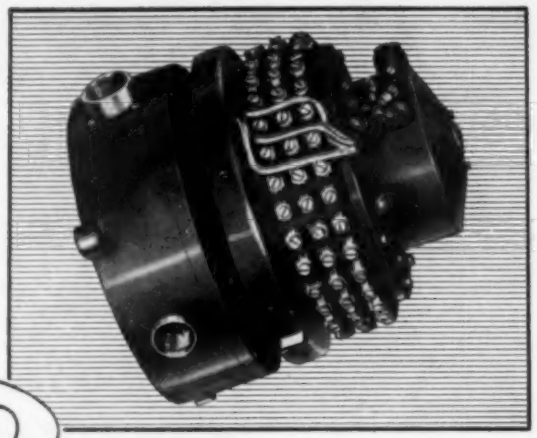

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Acceleration	To BSS G. 100
Weight	13¼ lbs.
Connections	From intervalometer—5 pin climatic proof breeze plug. From A.C. supply—4-pin climatic proof breeze plug.
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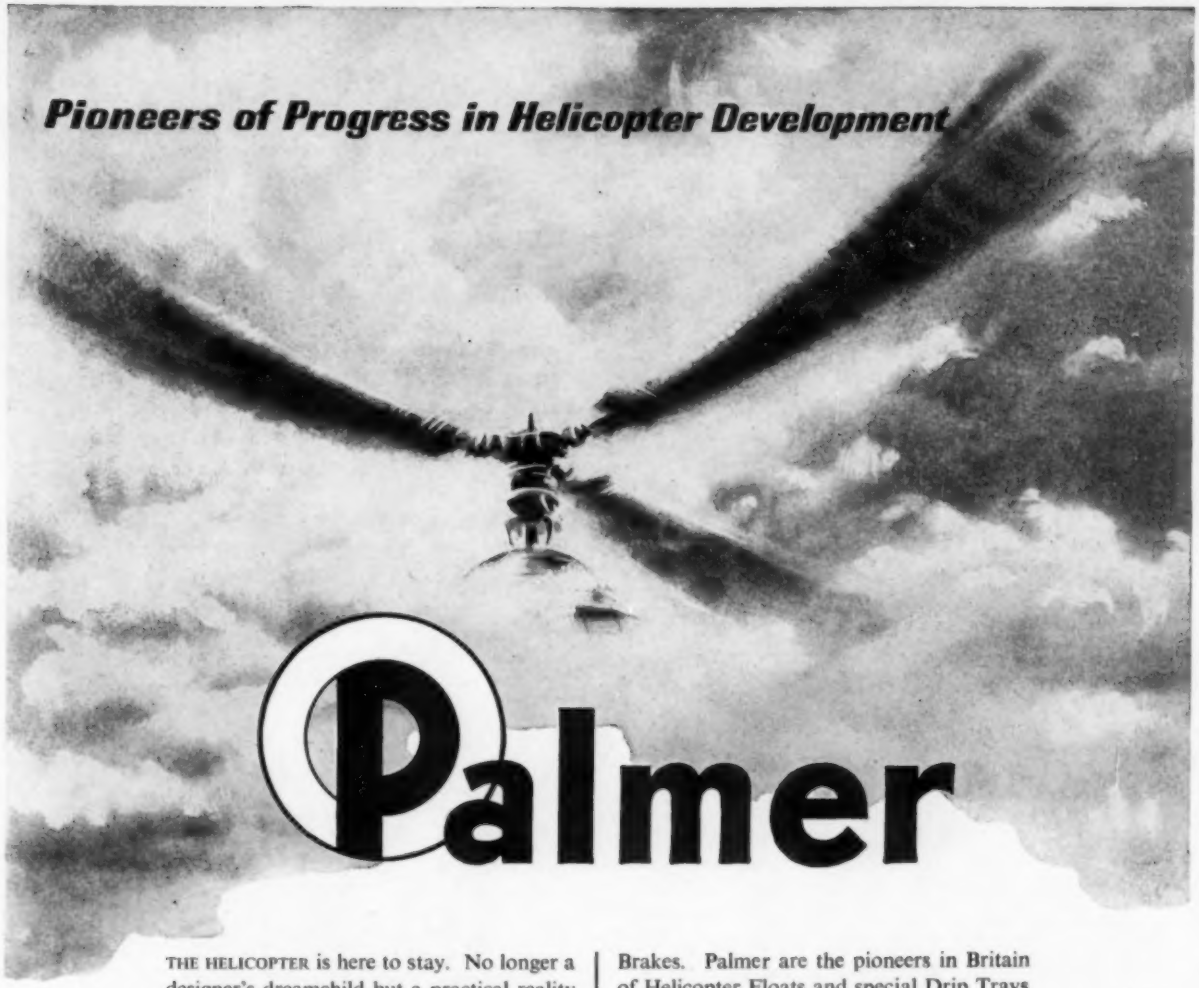

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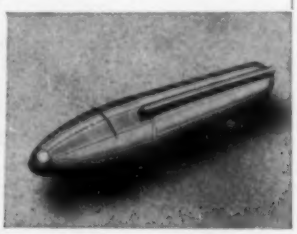

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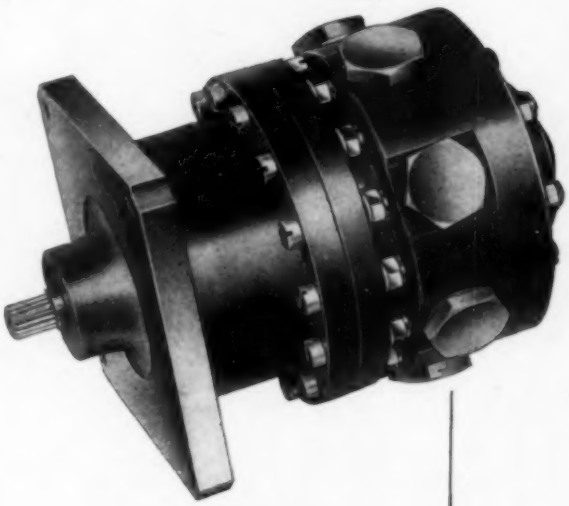

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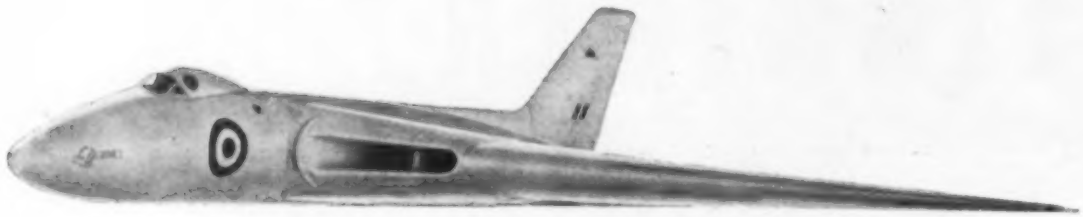

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Accelerated Development and Delivery

IN announcing the plans to speed-up aircraft development (on our late-news page last week) we remarked that there was nothing novel about the proposals. The Minister's reference to "new" arrangements meant simply new as a Ministry of Supply practice. In America it has been customary for a long time to order a sizeable number of prototypes of selected new military aircraft. It has been clear for several years past that considerable advantages were to be derived from the ordering of what amounts to pre-production batches rather than two or three prototypes. That this has seldom been done is indicative only of a lack of money and, to some extent, a short-sighted view. We cannot blame anyone for the former.

So far as the short-term outlook is concerned, it probably took time and study to convince those concerned solely with money that to spend heavily on even a good risk—to back a paper design in fact—was a reasonable action and one which, in the long run, would result in an overall saving. Late in coming though the decision is, it is nevertheless warmly welcomed by the industry.

How many prototypes should be ordered clearly depends upon the individual aircraft. Generally speaking, twenty or thirty fighters would be a reasonable compromise number allowing for initial development of airframe and power installation and then—simultaneously—controls, engines, radar equipment, weapons and the whole as a Service weapon. Experience has also shown that a margin has to be allowed for one or two prototypes likely to be lost through accidents. In the case of large aircraft five to ten prototypes may be a fair target number. Air frame and engine manufacturers, radar equipment makers and Service establishments will still have a call on them, but their size and carrying capacity will permit several kinds of trials to be undertaken on a single flight.

We would here state our agreement with Sir Roy Dobson that a great deal of time and expense can—and should—be saved by even more extensive testing of systems and equipment on the ground, in advance of the first flight and afterwards.

Many an aircraft has been sadly delayed by a few items of equipment delivered late or found wanting at the flight-trial stage. Equally serious is the case of the bomber or fighter introduced into squadron service while still lacking so much of its essential military equipment that it is no more than a peace-time vehicle. Lack of co-ordination in production and delivery of aircraft and their military equipment is doubly serious, for the presence of outwardly complete aircraft with Service markings at airfields around the country can lead to dangerous complacency. The bomber that cannot bomb and the fighter with operational limitations are little more than hollow mock-uppery.

Helicopters should be Included

THIS special number is a most appropriate one in which to consider helicopter development in relation to this newly adopted speed-up scheme for high-priority aircraft. We believe that many readers may be more than surprised to discover from the review on pages 293-308 just how many types of helicopters are flying—particularly in America. And even this review cannot bring home the very large numbers or individual well-developed designs now in operation with the American forces.

Certain it is that although the rotorplane will not replace entirely any type of fixed-wing machine it is essential in certain military rôles, and without doubt it is needed for civil duties as well. For the next several years it alone will be able to tackle work requiring hovering and vertical lifting.

Features in this issue of *Flight* indicate that, while most promising designs are being developed by British manufacturers, the country is far behind the Americans in scale of production and application. Recent remarks by Mr. Peter Masefield and, last week, by Lord Douglas, make it clear that B.E.A. may seek to continue its trials and operations with some new American machines while waiting for British types.

If British development is to catch up with that of America, or even keep in step closely behind it, a change of attitude will be required. More research will have to be authorized and more prototypes ordered: enterprising designers will have to be encouraged to take Comet-leaps ahead.

"A MOST IMPORTANT STEP" was last week's assessment, by the Under-Secretary of State for Air, of the equipment of the first R.A.F. squadron with Vickers-Supermarine Swifts. The squadron concerned—No. 56—took over the first of its new machines several weeks ago, after many of its maintenance personnel had attended a special course at Supermarine's South Marston works. Depicted in this "Flight" photograph is the blue-painted Swift F.4 prototype WK198 (reheat Avon).

FROM ALL QUARTERS

Air Power Debated

ALTHOUGH there were marked differences of emphasis and argument, the broad concept of air power as the dominant weapon in modern war was well sustained in the House of Commons last week, when the Defence and Air Estimates were considered in debate. Certain reservations were made as to the effectiveness of any fighter screen, however versatile, but few disputed that the policy of the Royal Air Force should be one of strength through quality and hitting power.

Nor was there much significant criticism of the NATO strategy of defence in depth as expounded by Mr. Nigel Birch, Parliamentary Secretary to the Ministry of Defence, and later by the Prime Minister in a typically thought-provoking contribution. Both took for granted—though some Members did not—the wisdom of building up a British strategic force of medium bombers as our main contribution to the deterrent or, should the deterrent fail, as the most immediate offensive weapon.

Mr. Birch was able to announce the decision of the U.S. Government to place certain substantial further orders in the United Kingdom for aircraft and ammunition for allocation to the Royal Air Force. The U.S. Government had already allocated some $110 million (nearly £40m) for the placing of contracts during 1953-54, and almost as large a sum was being requested for 1954-55.

In presenting his Department's Estimate for approval, Mr. George Ward, the Under-Secretary for Air, said that financial provision had been made for some Valiants to be delivered into squadron service during the coming year. The development of the Vulcan and Victor was going well, and it was hoped they would not be far behind the Valiant. It was to be noted that these aircraft would be two-and-a-half to three times as effective as their 1945 counterpart in altitude, speed and range. [Taking the "1945 counterpart" as the Lancaster, with a maximum speed of 275 m.p.h., the V-bombers might be supposed, on the basis of Mr. Ward's remarks, to have all-out speeds between 685 and 825 m.p.h. It would be more reasonable, however, to assume that he had in mind an operating speed of some 200 m.p.h. for the Lancaster and of 500-600 m.p.h. for the three jet bombers.—Ed.]

Defensively, a most important step had been taken by the re-equipment of the first squadron in Fighter Command with Swifts, while the Hunter was also expected this year. Development of the all-weather, all-important Javelin was going well.

The size of our existing night-fighter force would be nearly doubled during the coming year, and a new mark of Venom was to be introduced. More than half this force would be fitted with a new form of radar that would treble the area of search.

Generally, it was expected that more than half our regular force would consist of British swept-wing fighters by this time next year; Sabre squadrons would do much to strengthen quality during this interim phase.

But the effectiveness of re-equipment would be much reduced if the country's radar defence did not advance with the performance of modern aircraft. Having pointed the problem, but no more, Mr. Ward went on to discuss fighter control and to state that by the end of 1955 it would be possible to direct about twice as many formations of fighters against enemy bombers.

The first Command to complete its expansion and re-equipment, both of which were already nearly finished, would be Coastal. Some more Shackletons of an improved design and performance had been ordered. [Reference has unofficiallly been made to a nosewheel Shackleton.—Ed.]

The recent development of the Air Force had been on two main fronts—expansion of the front line and the preparation for new and more advanced aircraft coming in. Policy would continue to concentrate on quality and hitting power rather than on numbers. For example, the immensely improved cannon to be carried by the Hunter and Swift would increase the fire-power of the day fighter force by more than nine times in the coming year. [Although it is common knowledge that both the Hunter and Swift are armed with four 30 mm guns, official confirmation of this armament has not yet been forthcoming.—Ed.]

As to the future, already a pattern of requirements for the next ten years was to be discerned. Developments in both aerodynamics and engine design gave promise of advances in performance far beyond those thought likely even a year ago, and were essentially based on the fact that, with the achievement of supersonic flight, performance could be increased so much that kinetic heat generated became a dominating factor.

It was hoped soon to have a glimpse of the next generation of fighters, and to be able to demonstrate an aircraft capable of supersonic speed in level flight—a project whose development would be hastened by the ordering of 20 pre-production aircraft under the new procedure. [The new fighter to which Mr. Ward alluded is believed to be an English Electric design.—Ed.]

During the debate, several Members strongly urged the need for a light fighter in the ground support rôle. References were naturally made to the Folland Gnat and to the Avro delta (see news item on this page), but Mr. Ward held tenaciously to the view that the light fighter involved sacrifice of versatility. While he regretted his Department had no requirement for the Gnat, he wished that project success elsewhere in the NATO alliance. He was not distressed by complaints that the 1953-54 Estimates had been underspent to the extent of some £20,000,000. There were several good reasons for this, including a fall in prices, accelerated deliveries in the last period of 1952-53, a reduction in the requirements for mechanical transport, and so on.

SUPERSONIC IN LEVEL FLIGHT is this Dassault Mystère IVB (Rolls-Royce Avon). It is the second French aircraft to achieve this distinction; first was the turbojet-cum-rocket S. O. Espadon. As reported on this page, Mr. George Ward has said that Britain may "soon be able to demontrate an aircraft capable of supersonic speed in level flight."

Avro's Fighter/Bomber

CANADA is the source of new, unofficial, information on the Avro delta-winged fighter/bomber, first announced in *Flight* of February 19th. Said to be an adaptation of a delta-wing supersonic intercepter now being built by Avro for the R.A.F., it will weigh 8,000 lb and take off fully loaded from a forward P.S.P. strip in less than 1,000 yd. A braking parachute will enable it to land in a similar distance.

The power unit is to be an axial-flow turbojet weighing less than 1,000 lb and having a thrust of just under 5,000 lb. The ground-support model should be capable of Mach 1 and the intercepter should attain Mach 2 at heights above 42,000ft.

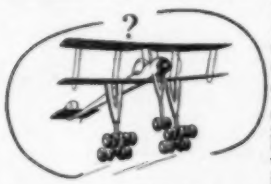
AIR MARSHAL S. ZHAVORONKOV, director of Aeroflot, stepping from an Air France Comet during his visit to Paris last week; he also inspected one of the Company's Viscounts, and made a tour of Orly Airport, before going on to Copenhagen to meet S.A.S. officials. Neither Air France nor the Soviet Embassy would comment on reports that the Soviet airline chief came to discuss direct services between Russia and France.

"Aries" Returns

ON Saturday last the Canberra *Aries IV*, which had been in Canada on arctic navigation flights for the previous fortnight, made a spectacular return by flying non-stop from Montreal to its base at the R.A.F. Flying College, Manby, Lincolnshire. The 3,300-statute-mile journey was completed in 6 hr 19 min. The Canberra was captained by W/C. C. S. G. Stanbury, D.S.O., D.F.C., and carried two navigators, F/L. R. F. Atkinson and F/L. H. T. Williams.

Aries, which was taking part in end-of-course training flights, had flown 14,000 miles since leaving Manby on February 16th.

Reminiscences of the "504"



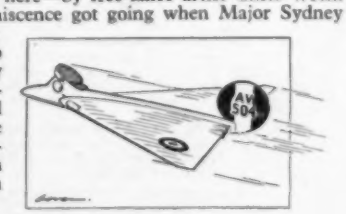
LAST Friday's third annual reunion dinner of the Avro 504 Club was even more successful than the previous occasions. The organizers — particularly Mr. J. C. C. Taylor, supported by Sir Roy Dobson—are to be congratulated. The simple aims and activities of the Club—whose existence is to be perpetuated by the addition to its membership each year of the best Avro apprentice —might well be taken as an example by others. At the annual dinner everyone makes a very brief speech, and recollections of achievements and events during the earliest days of Avro have each year been instructive and usually most amusing. They will certainly establish a tradition for the members of years to come.

The set toasts were those of "The Company," proposed by Mr. Fred Holmes, M.B.E., A.F.R.Ae.S., described as "Gentleman Apprentice No. 2." He talked of his experience of operating 504Ks for over 20 years "with never a bang from the engine or a scratch for a single passenger." The machines stood up to real punishment. He recalled operating, flat-tyred, from a glass-littered racecourse, and from a steam-rolled potato field at Ilkley; and there was an occasion when one machine flew from Birkenhead to Aintree with another Avro fuselage strapped to its side. There had been another incident at Aintree when a 504 turned over on its back but, after being righted and having had a dent knocked out of the leading edge with a broomstick, flew home. Other memories were of a night-flying display with fireworks at Stoke-on-Trent in company with O. P. Jones, "Joe" Taylor and "Scruffy" Robinson. As another indication of what the 504 would take, Mr. Holmes mentioned wing-walking episodes and loops with Martin Hearn standing in straps on the centre section.

Sir Roy Dobson, C.B.E., J.P., F.R.Ae.S., made a brief reply to the toast and handed over to Sir Alliott Verdon-Roe, O.B.E., F.R.Ae.S., who proposed "The memory of the Wrights." He recalled going to France to see Wilbur and Orville in 1908. It was strange, he thought, that the Wrights had seemed to stop after their first efforts, rather than go on to develop machines of the more modern kind. At the end of the speech Sir Alliott presented the 504 Club Trophy to Mr. Ian Goldberg, best apprentice for the year 1953 and second apprentice member; the first, also present, was Mr. J. Taylor.

The dinner menu was amusingly decorated with sketches—two of which are reproduced here—by free-lance artist Chris Wren.

The speeches of reminiscence got going when Major Sydney Sippe, making his first appearance at a Club dinner, told the *real* story of the 504 raid on Friedrichshafen—the first raid in which bombs were dropped in anger, mechanically released, on an organized raid with a definite objective.



C.A.S. in the United States

THE Chief of the Air Staff, Air Chief Marshal Sir William F. Dickson, left Britain last Saturday for a 12-day visit to the United States. With General Twining, U.S.A.F. Chief of Staff, he is discussing matters of common interest, including co-operation between the United States Strategic Air Command and R.A.F. Bomber Command. This last item is presumably the outcome of the recent disclosure that the R.A.F. possesses atomic weapons and that the U.S.A. now wish to share atomic knowledge with certain other countries. Sir William is also visiting General Curtis Le May at U.S.S.A.C. headquarters.

Accompanying the C.A.S. is A.V-M. L. F. Sinclair, Assistant C.A.S. (Operations).

Stop-press Helicopter

AS invariably seems to happen on such occasions, immediately the main body of this special Helicopter Number had gone to press the news arrived of another new type. Designed by the German Professor Focke at the Aeronautical Technical Centre of Sao Jose dos Campos, Sao Paulo (where the professor has been working since 1951), it is said to be capable of speeds of up to 330 m.p.h. Furthermore, it will "exceed in size and capacity any helicopter yet constructed." It is designed to ascend vertically and then to extend wings from the fuselage.

New R.A.F. Commissions

UNDER a new scheme for direct commissions in the General Duties (flying) Branch of the R.A.F., future aircrew officers will join for 12 years, with an eventual opportunity of obtaining a permanent commission.

An Air Ministry announcement states that it is expected that there will be enough places for permanent officers to provide for all who want to stay, and that many who do so will have the opportunity of reaching high air rank, with full career prospects, in the General Duties Branch, in the Technical Branch (which will be involved in guided-weapon projects), or in one of the other major ground branches.

It is hoped that others will serve until the age of 50. In such cases the ceiling rank will be wing commander, with pay and allowances totalling £1,750 and retirement pension of £675 p.a. This improvement in long-term prospects for those not in the full career-stream is provided for by extending the G.D. Branch to cover such duties as direction of interceptions, general control of aircraft landings and interpretation of photographs.

The officer of the future, holding a permanent G.D. commission, may have tours of flying duties up to the age of 43.

Finally, for those who do not wish to devote their full working lives to the Service, there will be an option to leave after eight years with a resettlement gratuity of £1,500, or to complete twelve years and receive a gratuity of £3,000, in both instances tax free.

Jet-Age Instrumentation

SOME important new developments in flight instrumentation are revealed by the Sperry Gyroscope Co., Ltd. In notes introducing their "Duplex Flight Data System" they state:—

"The introduction of high-speed aircraft, flying at high altitudes, into normal commercial operation has brought to the fore the urgent requirement for greater accuracy from the azimuth and attitude indicating instruments to enable the human pilot to fly his aircraft within the very fine limits necessary to maintain operational efficiency.

"Particularly with the jet and prop-jet transport aircraft, small changes in pitch result in large speed changes which cannot be accepted if correct "cruise control" is to be maintained; equally, a small error in heading represents a large error in "off-track" over a very short period. Thus the emphasis is on flight instruments having a high degree of accuracy and reliability and providing a presentation of attitude and heading such that the pilot's response is instinctive and immediate. The human pilot requires the necessary tools to enable him to maintain his aircraft on a flight path which accurately corresponds to the optimum flight plan."

To meet these requirements, Sperry have developed the new duplicated system, which is based on the following features: detector units at each wing-tip; duplicated azimuth and vertical gyros in the fuselage; a cockpit control-box; and duplicated flight instruments consisting of a Gyrosyn compass indicator and a horizon indicator for two pilots.

The gyros are mounted remote from the panel in sealed cases, and overhaul lives greater than 2,000 hr are confidently expected. Magnetic amplifiers ensure low weight and robust construction, and the system is so designed that it can be coupled with the autopilot, radio-magnetic indicators, flight directors and V.O.R.

FROM ALL QUARTERS . . .

The Barnwell Lecture

THE first Barnwell Memorial Lecture, marking the 25th anniversary of the formation of the Bristol branch of the Royal Aeronautical Society, was duly held in the Royal Fort Physics Laboratory, Bristol, on March 4th, as briefly noted last week. The lecturer, Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S., gave an enthralling and moving account of Barnwell the designer and the man—an account which was described by Capt. C. F. Uwins, in the course of subsequent reminiscences, as "an oration." Other memories were recalled by Mr. C. W. Tinson and Mr. L. G. Frise, both of whom worked closely with Barnwell for many years, and Sir William Farren, President of the R.Ae.S., added his own tribute. An account of the lecture will appear next week.

Helicopters in the Arctic

THAT use of helicopters in the Arctic would continue on an ever-expanding scale was emphasized recently by Mr. Frank N. Piasecki, chairman of Piasecki Helicopter Corporation. Making this statement in an address to the Montreal Section of the Society of Automobile Engineers, he went on to say that this expansion would bring about far greater exploitation of the vast resources now becoming available to the North American nations.

The development of transport helicopters, he continued, had come at a time when the need for such vehicles was urgent in polar areas. This need had been generated by a great influx of military material and by the acceleration of commercial exploitation of mineral and power resources in Canadian and Alaskan areas. Helicopters lent themselves particularly well to Arctic needs, because few other transportation facilities existed to handle the material and personnel movement that was now taking place. He also pointed out that existing means of transportation were seriously handicapped by the rugged terrain, snow, ice and freezing and thawing conditions.

"For the limited Arctic operations that have existed in the past years, the bush airplane has fulfilled a more prominent rôle than the airplane has enjoyed in most other areas of the world," he said. "This rôle is now being supplemented by the helicopter."

Mr. Piasecki added that primary problem in helicopter operation in the Arctic was the tremendous variation in temperatures.

Building the Martin Canberra

A LECTURE of the greatest interest to British aeronautical engineers was delivered in Washington recently under the auspices of the Society of Automotive Engineers. Mr. Glen Evans of the Glenn Martin Aircraft Company gave a paper on the production of the B-57A, the American version of the English Electric Canberra. His talk, illustrated by a number of excellent slides, was of particular significance because objective comparisons were made throughout between the British and American methods of doing the same job.

Mr. Evans described briefly how the Canberra had been chosen by the U.S.A.F. on account of its outstanding qualities, mentioning in particular its high manœuvrability. He outlined the changes which had been made; as *Flight* readers are aware, the Rolls-Royce Avon engines were replaced by Wright J65s, rotary bomb doors were incorporated and alterations were made to the cockpit.

The lecturer then dealt with a large number of production problems, pointing out the ways in which simpler solutions had been found and assembly made more suitable for an American factory. He pointed out that, whilst British practice led to the assembly of a large number of small components in one jig, the American method was to build up much larger components before bringing them together for final erection. He demonstrated the advantages of the trunnion-type jigs and "self-contained" fixtures.

A question in the subsequent discussion emphasized the important point that the American rate of production was considerably higher than the British, this of course having a large bearing on the tools used.

Mr. Evans brought out clearly the advantages of the American production-planning practice of starting with the end product and working backwards. He also drew attention to the significance of the rigid "time controls" employed by the Glenn Martin Company, which resulted in a close phasing of components and great accuracy in programme-keeping on complete aircraft.

The Glenn Martin Company had redrawn every part, he said, to take account of the differences between the basic standards of British and North American engineering practice and had run into numerous standardization problems, even on such components as rivets. Nevertheless, no major setback had been encountered, and he considered that two to three years had been saved in comparison with the time required for development and production of an entirely new aircraft. Finally, the lecturer expressed admiration of the basic simplicity of the Canberra design.

In the discussion which followed, Mr. Scott Hall, Head of Technical Services, British Joint Services Mission, paid tribute to the generosity of the Glenn Martin Company in their frequent acknowledgments of the English Electric Company's original Canberra design. He also pointed out that this was the most concrete demonstration possible of successful collaboration between the United States and Great Britain which was so essential for the future of civilization.

New Responsibilities for "Roly" Falk

ESTABLISHMENT of the new post of superintendent of flying is announced by A. V. Roe and Co., Ltd. Appointed to it is R. J. Falk, who joined the company in June, 1950, when he became primarily concerned with development flying of deltas. Henceforth, he will be responsible for all flying carried out by the company in addition to the special work required on experimental aircraft. Mr. J. H. Orrell, chief test pilot since 1947, continues duties in that capacity.

R. J. ("Roly") Falk

Fighter Command Chief on Designers

SOME entertaining remarks on aircraft designers as seen by their Service "customers" were made by Air Marshal Sir Dermot A. Boyle in an informal speech which he delivered as guest of honour at the recent annual dinner and dance of the Northern Heights Model Flying Club in London.

"To us in Fighter Command," said Sir Dermot (who is, of course, its A.O.C-in-C.) "good design is absolutely vital, and in my opinion there isn't a country in the world that can beat Britain at it."

The difficulty that a Service operating fighters was up against was to determine what would be wanted not next year, or the year after that, but in ten years' time. "In my experience," he continued, "you must ask designers for something quite impossible. Then there's a little muttering . . . 'Oh, we couldn't do that under eleven years'. But in the end they do it in nine."

Also present at the dinner was Air Marshal Sir Hugh P. Lloyd, who recently retired from the Service; he looked, if anything, even fitter than he used to do as A.O.C-in-C. of Bomber Command—farming in the Chilterns, it seems, is one good recipe for a happy and healthy retirement.

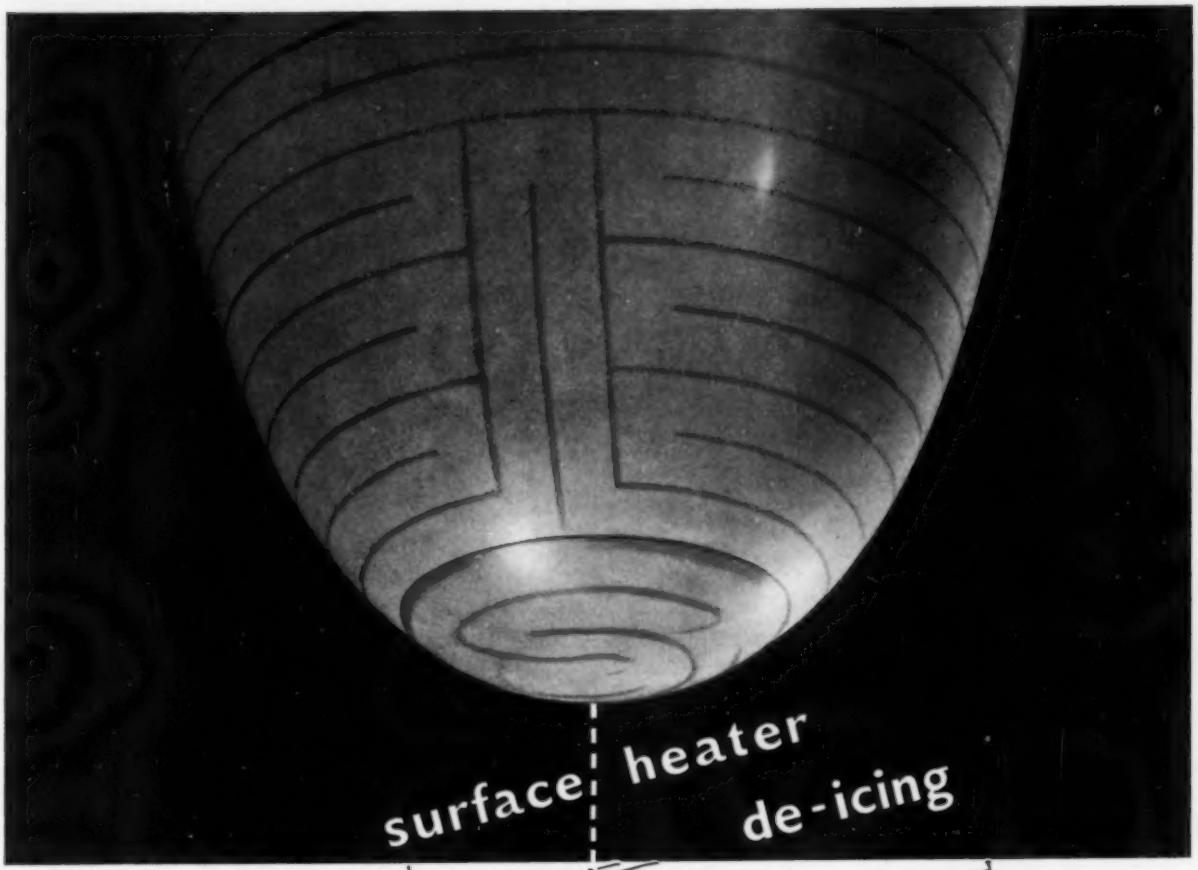
With the irrepressible Doctor Peter Thurston (N.H.M.F.C. president) in the chair, the evening was its customary success, and there was the usual "groaning board" of cups and trophies, duly presented with charm and grace by Lady Boyle.

Though it was clear that the Club had done well in the year's open competitions, one or two speakers hinted at a slight falling-off in interest in aeromodelling, at any rate in the London area; one of them wondered if television might not have been the reason. If members needed any encouragement, however, they received it from Sir Dermot Boyle when he promised to investigate the possibility of letting them have occasional use of a Service airfield in the London area for their flying activities.

FORTHCOMING EVENTS

Mar. 12. Royal Institution: "The Search for Lightness," by Hayne Constant, C.B.E., F.R.S., F.R.Ae.S.
Mar. 13. R.Ae.C.: World Gliding Championship Appeal Ball, Londonderry House.
Mar. 13. British Interplanetary Society (Midlands Branch): "Establishment of the Lunar Base," by R. A. Smith.
Mar. 13. British Interplanetary Society (Provisional Yorkshire Branch): "Man in Space," by H. S. Paiser.
Mar. 13. R.A.F. College, Cranwell: Hockey v. R.A.F.
Mar. 16. R.Ae.S. Section Lecture: "Development of the Spill Flow Burner and its Control System for Gas Turbines," by F. H. Carey, A.F.R.Ae.S.
Mar. 20. British Interplanetary Society (North-West Branch): Short-paper evening by members of the branch.
Mar. 24. R.Ae.C.: Annual general meeting.
Mar. 25. R.Ae.S. Graduates' and Students' Section: "Airworthiness Requirements for Landing and Take-Off," by L. J. W. Hall, Grad. R.Ae.S.
Mar. 27. Air-Britain: annual general meeting, Londonderry House.
Mar. 27. British Interplanetary Society (Provisional Western Branch): "An Engineer's Criticism of Some Space Flight Proposals," by F. R. Forbes Taylor.

Details of R.Ae.S. branch fixtures are unavoidably held over.



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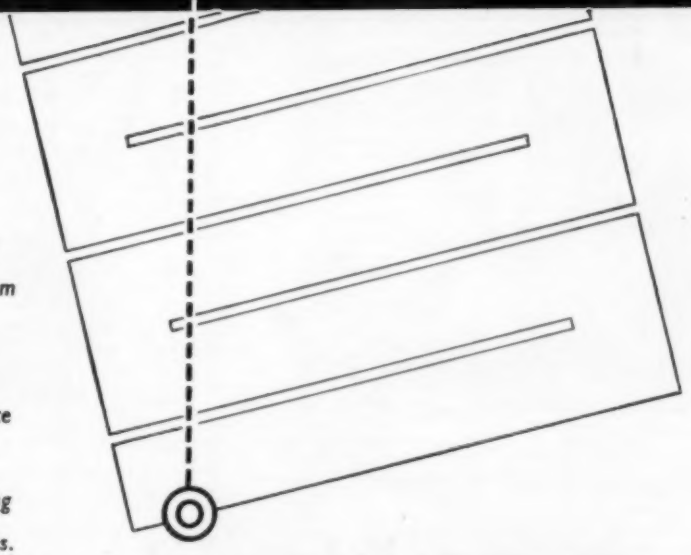

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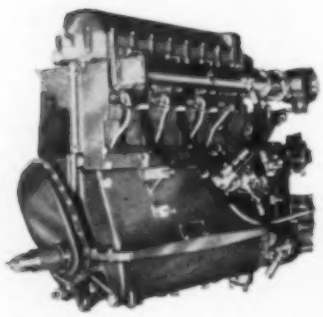

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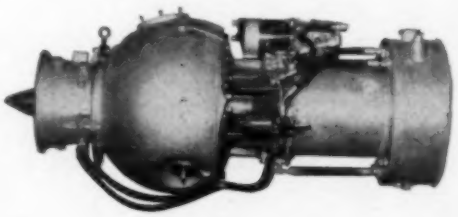

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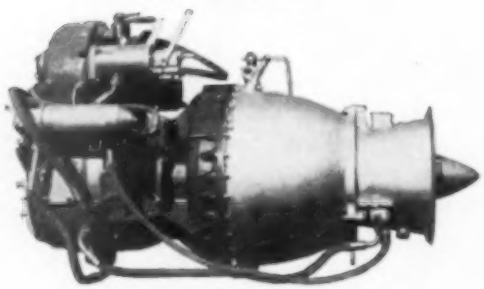

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CIVIL AVIATION

CIVIL AVIATION DEBATE

THE resumption of Comet services, and a new arrangement to reduce the inconvenience of the passenger embarkation tax, were announced by the Minister of Transport and Civil Aviation, Mr. A. T. Lennox-Boyd, in the House of Commons last Monday, during the debate on civil aviation.

Members strongly welcomed the Comet announcement (reported below) and were equally pleased to hear from Mr. Lennox-Boyd that agreement had at last been reached with the principal airlines that they would in future, for a special rebate in the passenger service charge, undertake to do their utmost to collect the charge when passengers bought their tickets. He said the new arrangements would start as soon as possible and would be subject to review from time to time and certainly within twelve months. He assured the House that he would not hesitate to cancel the special rebate for any operator if it was found that it did not successfully cut down the nuisance of collection from passengers at the airport. He really believed this modest arrangement would have an excellent effect on what was a particularly difficult problem.

Although Mr. Lennox-Boyd devoted most of his speech to a recapitulation of policy questions, he took pains to make the position of the North Atlantic freight services as plain as possible.

Asked why B.O.A.C. had withdrawn their application for such a service, he said he now understood that the Corporation had been considering the possibilities of co-operating with independent companies in the development of all-freight services, rather than of operating a competitive and independent service. They had been exploring with Airwork the possibility of such a co-operative arrangement on the North Atlantic.

Particular criticism was levelled by Mr. Frank Beswick (Lab. Uxbridge) against the three-fare system applying to Colonial Coach services, in particular on the East African and Cyprus routes. Mr. Beswick suggested that this represented a breach of the agreement made under the 1949 Act which provided that the Corporation would only make agreements with the different firms concerned on the basis "that the agreement is calculated to further the efficient discharge of the functions of the Corporation."

Mr. Lennox-Boyd denied that such a charge could be supported by the facts and commented that experience in East Africa had shown more than enough potential traffic for both public and private enterprise. He spoke most enthusiastically of the intervention of shipping companies in the air-freight field; it was his belief that shipping capital would find a most useful outlet in the large freight markets of the world to which the Corporations, by the nature of their make-up, could not render the fullest possible contribution.

Mr. Beswick also complained that last week the Board of B.O.A.C. had found it necessary to approach the Minister to protest against recent actions taken by him; Mr. Lennox-Boyd confirmed that a meeting had taken place at B.O.A.C.'s request and said it had been highly profitable to both sides.

COMET SERVICES FROM MARCH 23rd

THE text of the official statement on the resumption of Comet services, issued on Monday, was as follows:

"B.O.A.C. announce that the modifications which they are making to their Comet aircraft as the result of detailed inspection following upon the loss of Comet G-ALYP near Elba and as agreed with the Air Registration Board and the manufacturers, are approaching completion.

"Subject to the outcome of the necessary flight tests being satisfactory, normal passenger services will be resumed on the Johannesburg route on Tuesday, March 23rd. Other services will be announced to follow.

"The Minister of Transport and Civil Aviation, who has taken the advice of the Air Registration Board and the Air Safety Board, concurs in this decision."

Comets operated by the French airlines Air France and U.A.T. will also return to service in the near future.

ELBA SALVAGE OPERATIONS

PROGRESS made so far in recovering portions of Comet G-ALYP from the Mediterranean and the difficulties faced by the Naval salvage team have been outlined by the Commander-in-Chief, Mediterranean, Admiral the Earl Mountbatten of Burma. Recovery operations are under the command of Captain McMullen and the vessels engaged in the search are *Sea Salvor*, *Barhill*, *Whirlwind* and *Sursay*. In addition, says Earl Mountbatten, the fleet has been assisted by chartered Italian trawlers and "the British salvage firm Risdon and Beasley have been of the greatest help; we are proud to note that their magnificent divers, Mr. Bray and Mr. Gilpin, are ex-Naval men."

On the difficulties of the operation he notes that "We have had to work in depths varying from three hundred and sixty to nearly six hundred feet—far deeper than would be considered profitable by commercial salvage companies. . . . In the calm summer Mediterranean weather, one can easily see a hundred feet at a depth of a hundred feet. In the disturbed winter water, at five hundred feet, one is lucky if one can see ten feet, either by direct vision from the observation chamber or by under-water television camera. . . . The wreckage is spread far and wide, and is extremely difficult to locate. It is rather like searching for a handful of peas in a one-acre field from a helicopter on a misty day. It was the Pye TV camera, operated by the fast frigate *Wakeful*, which first caught sight of a piece of the Comet—a truly remarkable achievement in the light of the above comparison."

Earl Mountbatten adds that: "Smaller items have also been fished up in the trawls. We have recovered barely one tenth of the Comet in six laborious weeks of unremitting toil, during which we have expended 2,000 tons of oil fuel and supplied 140,000 man hours of work. Unfortunately, it is mainly the tail section which has come to light so far, but the passengers' bar, which has been found, was at the fore-end. A large part of the wreckage is at present on board the fleet tug *Brigand*, on its way to Malta for onward shipment in the Fleet Auxiliary *Fort Beauharnois* to the United Kingdom. The part we are most anxious to get up is the centre section, with the engines, but that will take at least another five or six weeks, even if we are very lucky."

SABOTAGE IN INDO-CHINA

DAMAGE estimated at £2m is reported to have been caused by Viet-Minh saboteurs during the night of March 3rd at Hanoi, the civil airport for Guilam, Viet-Nam. Two DC-3s were completely destroyed and four more seriously damaged. Other badly damaged aircraft include a Bristol 170, a Beaver and two of the five Boeing Stratoliners operated by Aigle Azur. The Stratoliner was the first large pressurized transport, and the Aigle Azur machines are among the last surviving examples.

Hanoi is a terminal for the air lift in support of anti-rebel forces, which will be seriously affected by the damage. The Formosa-based American-Chinese airline, Civil Air Transport, is reported to have been awarded a French government contract to operate 12 C-119 Packets in support of the Union forces. The first of 24 C.A.T. pilots who will fly the aircraft were due to arrive in Indo-China this week.

HELICOPTER CENTRE AT DERBY

FIRST details of a plan to make Derby a centre of helicopter activity in this country have been announced by G/C. C. A. B. Wilcock, O.B.E., A.F.C., A.F.R.Ae.S., M.P., chairman of Air Schools, Ltd., and of the subsidiary companies Derby Aviation, Ltd., and Wolverhampton Aviation, Ltd. We understand from G/C. Wilcock that a special division of Derby Aviation, to be known as the Helicopter Centre, is being formed to undertake three separate rôles associated with rotorcraft: (1) sales, repair and maintenance; (2) training of pilots; (3) advice on various problems that may face helicopter operators and municipalities.

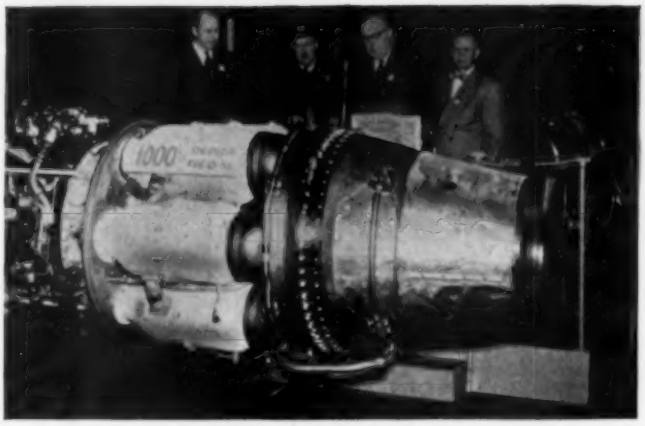
G/C. C. A. B. Wilcock.

Helicopter agencies are under negotiation, and G/C. Wilcock hopes that at least one type of helicopter will soon be available at Derby for demonstration purposes. Arrangements are being made for training of Derby Aviation pilots and ground-staff, and for laying-in spares. Hangar accommodation has already been set aside. G/C. Wilcock adds that the Ministry of Transport and Civil Aviation, the Air Ministry and the Admiralty have been notified of the scheme, and that they have all shown interest in the proposal. He feels that municipal authorities will find the Derby establishment particularly useful in formulating their plans for building helicopter sites, since it will provide them with an opportunity to study actual operations at first hand.

The Air Schools group's experience in the fixed-wing field is considerable, and includes the training of 14,000 R.A.F. pilots at their now-defunct reserve schools; the operation of flying clubs at Derby, Wolverhampton and Elstree, and of scheduled services at Derby; and sales, maintenance and repair of aircraft at both Wolverhampton and Derby. G/C. Wilcock has been M.P. for Derby since 1945.

HERE AND THERE

U.S. SENATORS Stuart Symington and Styles Bridges at Dunsfold after a Hunter demonstration by S/L Neville Duke. Accompanying them are: (left) J. T. Lidbury (general manager) and Sir Sydney Camm (chief designer) and (right) Neville Spriggs (managing director).



1,000th ORENDA is handed to the R.C.A.F. by Avro Canada.

(Left to right) Crawford Gordon jnr., president; A. V-M. Smith, Air Member for Technical Services; W. R. McLachlan (vice-president, gas-turbine division); and Harold Robins, the employee who made the presentation.

Exports Up Again

JANUARY figures, published last week, show that British aviation exports totalled nearly £5½ million—£1m more than for January last year. Engine exports, listed separately for the first time since October 1951, brought nearly £2m of the £5½m.

Bristol Chief for N. America

LAST Friday Sir Reginald Verdon Smith, joint managing director of the Bristol Aeroplane Co., left London Airport for the U.S.A. and Canada. He would not say whether his talks in America would concern Britannia production, but in Canada he will discuss the building of the maritime version.

Farnborough—the Date

WE continue to receive many enquiries as to the date of this year's Farnborough Show; so we repeat—Tuesday, September 7th, to Sunday, the 12th, inclusive.

R.A.F. Helicopters in Malaya

THE only operational helicopter squadron of the R.A.F., No. 194, has just celebrated its first birthday. Formed at Singapore, it took over the duties of the former Far East Casualty Evacuation Flight, then moved to its present base at Kuala Lumpur. During the twelve months its Westland-Sikorsky Dragonflies have flown over 3,000 operational sorties in Malaya, mainly on casualty evacuation, but also in searching for terrorist hide-outs. The C.O. is S/L. C. R. G. Henderson. Helicopter operations in Malaya—by a Naval squadron—are described in this issue.

Production in Print

A JOINT "conference on production information" is to be held by the Institution of Production Engineers and the aeronautical and engineering groups of A.S.L.I.B. at the College of Aeronautics from April 2nd to 5th. Among the speakers will be Prof. J. V. Connolly (head of the College's Department of Aircraft Economics and Production), G/C. G. W. Williamson (technical adviser to Short Bros. and Harland, Ltd.) and W. E. Goff (editor, *Aircraft Production*). Reservation forms—which must be completed by March 25th—are obtainable from C. W. Cleverdon, Librarian, College of Aeronautics, Cranfield, Beds.

M.T.C.A. and M.Inst.T.

AT the recent annual dinner of the Institute of Transport, the president, Sir John Elliot, M.Inst.T., announced that his successor in office for the session commencing on October 1st, 1954, would be Sir Gilmour Jenkins, K.C.B., K.B.E., M.C., M.Inst.T., Permanent Secretary of the Ministry of Transport and Civil Aviation. Sir Gilmour, who was present at the function, was elected a member of the council in 1951 and became a vice-president in 1952.

D.H. Engine Company's Move

AS from next Monday, the registered offices and administrative H.Q. of the de Havilland Engine Co., Ltd., will be moved to the main production factory at Leavesden Airfield, Herts (Garston 2261). The engineering division, with its design and experimental staffs, remains at Stonegrove, Edgware.

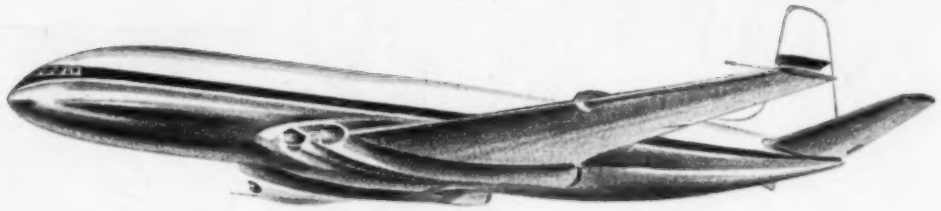
Atomically to Australia

A REMARK by Sir Arthur Gouge at the recent dinner given by Mr. James V. Martin suffered an error of transcription in our report of the event. His reference to atomic power and its possibilities, and the statement that it would open the way to flights outside the atmosphere with nil resistance, should have concluded with the words "Vehicles of this sort will probably fly to Australia in three to four hours."

New World Speed Record

ALTHOUGH it was set up as long ago as last October 29th, the present world absolute speed record has only just been ratified by the F.A.I. The record was established by Lt-Col. Frank K. Everest, U.S.A.F. (of the Flight Test Center at Edwards A.F.B.), flying a North American YF-100 Super Sabre; his speed over four runs is confirmed at 755.149 m.p.h. This was the first record to be established over a 15-km course and therefore did not have to beat the previous figure (Lt-Cdr. Verdin's 752.944 m.p.h. in a Douglas Skyray) by the usual 1 per cent.

JAP CONTENDER: The Kawasaki KAT-1, of which the first prototype is seen below, is intended as a trainer for the National Safety Force. It is thus a direct competitor of the very similar Mentor, 30 of which are being built this year by Fuji under licence from Beech Aircraft. Kawasaki are repairing U.S.A.F. F-51s, F-80s and T-33s, and will shortly build the T-33 and F-94C.



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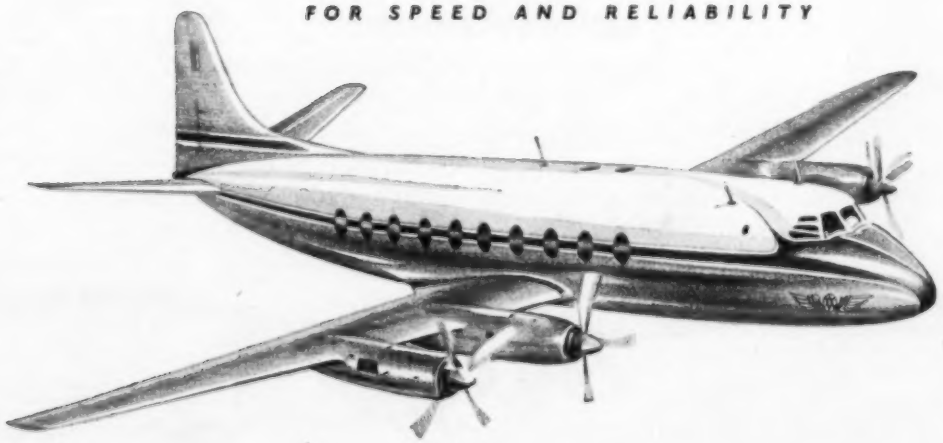

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VIEWS on the HELICOPTER

Pioneers, Designers and Constructors Send Special Messages to "Flight"

O. L. L. FITZWILLIAMS,
B.A., A.F.R.Ae.S.

Chief Designer (Helicopters)
Westland Aircraft, Ltd.

IN offering a personal view of helicopter possibilities I find it comforting to remember that procrastination, being the thief of time and therefore the mother of necessity, is frequently also the grandmother of invention. In helicopter development we have certainly procrastinated and now face a clear necessity for vigorous action to offset the accelerating pace of American achievement. For such action to be effective, without the sort of massive government support which chiefly propels the American industry, I believe we now require not merely inventions but also a few miracles in the reorientation of our thinking about the helicopter.

The poor economics of the existing types of small helicopter not only rule out anything approaching a mass market, but also bias development prematurely toward increasing size. In terms of conventional, and therefore expensive, designs this means a heavy bias in favour of projects which rely entirely on government support. With one or two important exceptions for military helicopters in the medium-size range, such support on an adequate scale is now available only in the United States. Moreover, the problem of noise and the rapidly (and rightly) increasing severity of civil airworthiness requirements introduce a formidable element of uncertainty in respect of the economics of large passenger helicopters, particularly for operation from city areas; so serious production of airline helicopters is at present unlikely, except as a by-product of military expenditure on the American scale.

In this country development of the new conventional helicopter must continue to be pressed with vigour, since the survival of our small industry still depends on meeting the limited but important military and civil requirements for which government support is available. However, should such support remain at approximately the present level (as now seems likely) it is difficult to avoid the conclusion that our position in the export market may shortly deteriorate to the point of extinction unless we are able, from our own resources, to apply a sharp corrective to present trends.

In my view our circumstances dictate that this corrective should take the form of a successful solution to the problems of the small helicopter in the two-seat to six-seat size range. It is my personal belief that a switch is now possible from mechanical drive to a really efficient form of blade-tip propulsion which will enable us to make these machines much easier to fly, with a much higher standard of performance and greatly improved handling characteristics, eliminating all objectionable operating limitations. I believe also that in these machines we can attain a degree of simplicity and safety sufficient to justify an approach toward the mass market and volume production. In consequence I think it reasonable to expect greatly reduced purchase and operating costs, falling ultimately to as little as one-tenth of present values.

If we could get such machines on the market in the early 1960s we would have little to fear for the future of the industry, which would be well on the way to a profitable and almost explosive expansion in helicopter size as well as in production volume.

G. GLASSER

President
Société Nationale de
Constructions Aéronautiques
du Sud-Ouest (S.N.C.A.S.O.)

TODAY it is commonplace to state that a great future lies ahead of helicopters and of machines of the combination or convertiplane type which employ (simultaneously or alternately) the flying principles of both the helicopter and the fixed-wing aircraft.

Bearing in mind the tremendous advantages they afford for all work over short stages, one is only surprised, in fact, that these new flying machines have not been developed more quickly. The main reason for this lies in the high cost; this applies as much to purchase as to operation. The high price is an indication of their mechanical complexity and of the difficulty of perfecting them.

Since the Korean war provided the opportunity to demonstrate incontrovertibly the usefulness of helicopters for military operations, the United States has devoted large sums of money to their series-production and to the development of new types. This action has led to the extension of the helicopter's sphere of operations, and it is now starting to overflow from the purely military fields into those of private and commercial flying.

European countries, on the other hand, lacking the military stimulus to press forward with helicopter construction, and having neither the financial resources nor the numerous outlets, have fallen seriously behindhand in these developments.

In France, since World War II, S.N.C.A.S.O. has persevered with the design and development of gas turbines and reaction nozzles to power helicopters. These methods of propulsion have led to simple, light and economic machines which, over short ranges, show considerable advantages in comparison with existing conventional helicopters with mechanical drives. Moreover, the lightness of these turbines permits the duplication of power units, thereby enabling one of the most onerous requirements for commercial transport to be complied with.

Turbines and tip-jet propulsion offer promising solutions to the power requirements of the convertiplane, for such machines are at a disadvantage from the weight point of view if a conventional piston engine is used to provide motive power for both forward thrust and rotor drive. These combination aircraft will, in the future, be the most rapid means of transport between communities several hundred kilometres apart. Using heliports of small area in the very centre of towns and cities, they will possess, at the same time, a speed almost equal to that of piston-engined planes, thus permitting the actual journey time to be reduced by more than fifty per cent.

Many years of hard work precede the development of practical and economic rotorplanes suitable for wide commercial application, but I am convinced that the construction of helicopters, and of other aircraft capable of vertical as well as of horizontal flight, will soon constitute a large and settled industry.

R. L. LICKLEY,
B.Sc., D.I.C., M.I.Mech.E., F.R.Ae.S.

Chief Engineer
Fairey Aviation Co., Ltd.

THE helicopter creates a new form of transport: neither a substitute for the aeroplane nor a replacement for a bus service, it will, if properly used, make a change in transport comparable with that produced by railways in the last century. Helicopter characteristics enable places to be linked without reference to existing aerodromes, roads, or railways, without the difficulties caused by stretches of water and, except in mountain regions, without reference to surface contours.

The type of helicopter at present flying cannot yet meet these transport requirements. It is slow; has, by turbine airliner standards, considerable vibration; is not yet as reliable as conventional airliners; has a high initial cost in relation to payload and a high operating cost. Before full use is made of helicopters in transport, these deficiencies must be overcome.

Various ways of increasing cruising speed have been suggested, but most promising is that of unloading the rotor by fixed wings. This logically leads to the use of propellers to give forward thrust, and to give it more economically than by tilting the rotor. A combination at cruising speed of autorotating rotors and a loaded

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wing reduces the vibration level and enables much higher speeds to be attained.

The large rotors needed will require tip drive. Mechanical drive has proved efficient and reliable in small sizes, but is heavy and complicates the vibration pattern of rotor and airframe. The simplification arising from tip drive, and the easier design-problems of head and blades, will lead to its use in all large helicopters. Gas turbines will be used in any case, and the vibration level, lowered by the methods outlined in the previous paragraph, will be further reduced and an acceptable standard reached.

Reliability is a major factor and will require great attention. Tip drive will simplify rotor design from a fatigue aspect; and this, combined with absence of gears and transmissions, will lead to longer life and less expensive rotor systems. Availability for flight for over 12 hours in any day will be essential and will demand good all-weather flying characteristics by day and night. A suitable autopilot will have to be developed, although this should not be so difficult in the type of machine with fixed wings. Adequate safety will also be needed in the event of partial power-plant failure; and, because of the areas in which operations will take place, complete power plant failure must not occur. It will be necessary to make use of all the experience of maintenance which the manufacturers and airlines possess.

High initial cost in relation to payload will go down as size increases but, in addition, design will have to go ahead to simplify construction and to lengthen rotor and engine life. Improved methods of production will also be needed, in order to get the numbers required without the elaborate and costly systems of tooling often used at present.

High operating costs drop steadily with increase in size and increase in reliability. A further improvement will result from the use of helicopters if loading and unloading times are kept to a minimum, as time at stops will otherwise add up to a large percentage of flight time; a wide field is open here for ingenuity and invention in bringing about better methods of loading both passengers and cargo.

Helicopters developed on these lines will weigh 55,000 to 75,000 lb, have cruising speeds of 175-200 m.p.h., and still-air ranges of 250 to 350 miles. Two of these machines in daily operation between London and Edinburgh will move the same quantity of passengers and luggage as two Flying Scotsman trains, but the journey time will only be 2¼ hours.

The machine will have many and varied uses in less densely populated and undeveloped parts of the world. Its short-haul capacity of 15 tons, and its independence of aerodromes, will render it ideal for economical development of new mining ventures, etc. It will also be of great use to the Army in the supply of forward areas, in operations over roadless country, and in linking detached units in the field. The use of this new form of transport would confer on the Army a manœuvrability of an order altogether different from that at present forced on it by dependence on roads and the three-ton truck.

These developments are possible and will come. How quickly they come will depend on the energy and effort put into basic research on the helicopter, both on the aerodynamic and structural sides; on the foresight used in placing orders; and on the efforts of the designers to get the last ounce out of the aircraft and the maximum reliability into it.

FRANK N. PIASECKI

Chairman
Piasecki Helicopter Corporation

THE great popularity of the helicopter has come, in part, from its ability to make power-off landings in a space not very much larger than the machine itself and its ability to ascend and descend vertically. When the feature of multiple power plants is added to the helicopter it will reach safety characteristics of the highest order known in air transportation.

In the future the principal technical advances in vertical-lift aircraft will occur in three realms: (1) Size and capacity; (2) speed; (3) development of their use.

The size and capacity of helicopters show no inherent technical limits. Larger and larger machines, capable of lifting heavier and heavier loads, can and will be built as commercial economics and military planning dictate. Even today we can foresee the design of helicopters over 200,000 lb in weight.

The most dramatic progress in the helicopter field will stem from increased speed, coming from two directions: helicopter designers will add speed to their machines; conversely, aeroplane designers will add vertical-lift capabilities to their high-speed craft. The result will be a blending of the two types of flight into machines fully capable of both helicopter flight as we know it today and high-speed flight at velocities far beyond even today's experimental supersonic speeds.

The fulfilment of these basic desires is fast approaching reality; the price of this realization, however, is unpredictable at the moment. It is possible that the combination vehicle will pay penalties of weight and complexity in either the aeroplane or helicopter flight regimes, or in both; on the other hand, it is possible that the price of the combination will be outweighed by savings in high-speed landing devices now required and by reductions in the tremendous capital investment necessary for airports. The possibility of such machines within the next two decades is unquestionable; their relative cost remains to be determined in the future.

One of the most challenging and promising technical avenues of advancement is the development of techniques and equipment (both ground and helicopter-borne) to permit widest and most effective use of the unique flight characteristics of the helicopter. Automatic flight systems will permit helicopters to operate in all forms of weather, even in obstructed areas such as the hearts of cities.

The greatest impact of the helicopter will be its effect upon, and integration with, our social system, transportation network, architectural design, city planning and location of industry. The size of metropolitan areas now generally considered to be one hour's commuting time by surface transit will be extended several-fold. *Lines* of transportation, now fixed by the pattern of railroads and main highways, will be supplemented by a new flexibility in the form of *areas* of transportation served by helicopter. This will be achieved at a capital investment lower than that inherent to any other form of transportation. For, unlike the railroad with its trackage and right-of-way, the automobile with its highways, the steamship with its harbours and docks, the aeroplane with its airports, the helicopter requires fewer supporting facilities than any other vehicle. Therefore, we can expect its development to be rapid.

There are no technical barriers to the progress of vertical-lift aircraft in sight. With proper planning and public support, the helicopter's scope will be unlimited. The best is yet ahead.

IGOR I. SIKORSKY

Engineering Manager
Sikorsky Aircraft Division of United Aircraft Corporation

The following are extracts from a statement made on behalf of Mr. Sikorsky; much of the remainder, concerned with performance and other details of his company's aircraft, is covered in our review of helicopters.

IN a year of important and far-reaching events, the really big news at Sikorsky Aircraft in 1953 centred about the first flights of the XHR2S, by far the world's most powerful helicopter. Commercially, the most important news of 1953 was the beginning by Sabena Belgian Airlines of its international passenger service in the lowlands of Western Europe. Servicing a network of eight cities in five countries, Sabena flies its S-55s twice daily over the route. By December, the service, which began on September 1st, 1953, had carried well over 3,000 passengers, the majority of them *en route* for hook-up with Sabena's overseas fixed-wing flights. In New York, New York Airways began a passenger service between the city's three major metropolitan airports. Also entering the helicopter passenger field in 1953 was National Airlines, a major U.S. trunk line carrier.

Of major importance in the field of helicopters for industrial use was the purchase and operation of an S-55 by the Hudson Bay Mining and Smelting Company, of Canada. By utilizing the unique advantages of helicopter operation in the rugged mountain territory of the Yukon and Northwest Territories, Hudson Bay more than tripled the area normally prospected in one season.

At this time, however, commercial availability of the S-56 appears two or three years away. But this time lag by no means indicates gloom by the Sikorsky company as to its immediate future.

Military demand stays high, development work is booming, and commercial prospects open up every day.

THE HELICOPTER INSTRUCTOR

—*and His Pupils: Things to be Learned and Unlearned*

By JOHN FAY

THE author of this article writes from experience gained while instructing pupils at Westland's helicopter school at Yeovil and from his helicopter career in general, which he began in 1944 after fixed-wing experience with the Fleet Air Arm. Until he joined Westland's in 1952 he was engaged on helicopter operational development with B.E.A. Readers interested in the subject purely from the pupil's angle may like to be reminded that in "Flight" of November 6th, 1953, the Editor described his experiences while qualifying for a helicopter endorsement under Mr. Fay's tutelage.

IN the early days of helicopter flight there were no dual-control types. The pioneers, such as Igor Sikorsky, had to test their aircraft and learn to fly them at the same time. With the introduction in 1942 of the dual-control Sikorsky R.4, the early pilots became the vanguard of an ever-increasing army carrying out a variety of piloting duties all over the world.

My own entry into the instructional field started in 1948. Since that time there have passed through my hands some ninety pupils, of whom about fifty had never flown helicopters before. This article is based on some of the aspects of instruction noted during pilot training.

As a general rule, pilots taking a helicopter course have previous fixed-wing experience. Variation in their abilities are accounted for mainly by their adaptability, experience and recent fixed-wing practice coming a late second and third. Although there can be considerable difference in pupils' abilities I feel that there is no reason why any fixed-wing pilot should not become completely competent in a helicopter. Unless an experienced fixed-wing pilot shows a marked dislike for helicopters (and some do), he should be able to finish the course satisfactorily. Pupils with no previous piloting experience are a different proposition, as they have to prove their skill in co-ordination, judgement, quick thinking, etc.; and if they fail to make the grade it is most probable that they would not have passed any course of fixed-wing flying either.

The first essentials for an instructor are: (a) pupils and (b) helicopters. Invariably one of these items tends to be in a considerable minority. This means that the other is left sitting in the crew room (or the hangar, as the case may be) with nothing to do. Assuming, however, that pupils, serviceable aircraft and reasonable weather bear some geographical similarity, then the first short period of dual instruction is devoted to flying straight and level with the pupil having control of the stick and rudder pedals only.

It is during this first exercise that an instructor can generally tell whether his man will solo quickly or whether he will take some time. Only a small number of pupils take to straight and level flying immediately and do not over-correct; these are the types who will solo in a very few hours. Pupils of average adaptability start big longitudinal swings, but soon settle down. Those who find difficulty in adapting themselves will require the instructor to take over several times to unravel the aerial knot for them.

The second exercise consists of medium turns. At this stage past training and air commonsense can be superficially assessed by whether the pupil turns his head and looks to see that all is clear. Frankly, I am aghast at the number of pupils for whom this is not second nature. Perhaps these pilots still have my "Turn your head first" ringing in their ears, just as I can still hear my E.F.T.S. instructor saying "Air-speed!" and various other things —mostly uncomplimentary.

Hovering exercises (stick and rudder pedals only) are given to the pupil after moderate proficiency in forward flight. One of the most difficult things is to instruct a pupil to hover, because there appear to be few straightforward rules to apply. If an analysis is made of the stick movements when hovering, these movements often appear to be completely illogical. Much of the instruction must be done by the pupil teaching himself by trial and error. There are some rules to apply, however, and two of them are (a) correct the swing first and worry about movement over the ground later; and (b) a big swing requires a big stick movement to correct it. But I find myself saying most often: "Don't move the stick about so much—make small movements." The pupil generally finds it difficult to obey this last instruction, but if the instructor grasps the stick firmly for a few seconds the needlessness of continual stick agitation can be demonstrated.

When the pupil advances to the stage of adding the throttle and collective-pitch lever to the other controls, the fun really begins, as he must then do several things at once. Remembering my own training, I try to keep the initial periods quite short, otherwise the pupil's mind tends to boggle and time will be wasted in the long run. Even so, attempts to hover often consist of a series of drunken leaps across the aerodrome.

Some years ago another instructor gave a pupil a short course and spent the usual time in teaching him to hover and fly the helicopter with average proficiency. Some days after the pupil had left, the instructor was somewhat shattered to receive a 'phone call from him and to hear him say: "I hate to ask you this, old man—but tell me, what *is* the stalling speed of a helicopter?"

However, although a helicopter cannot stall in the accepted sense, the rotor blades can lose lift if they are allowed to slow down too much. Unless recovery is made immediately the aircraft will drop out of the sky. The rotational speed of the rotor must therefore be retained *above* a certain minimum by use of the throttle. In order to avoid over-speeding the engine and/or rotor, the r.p.m. must also be kept *below* a certain figure. This is heart-breaking for the pupil, for the r.p.m. will tend to change with movement of rudder pedals and c.p. lever, with changes of air-speed, and with changes of g; and he becomes heartily sick of the instructor pointing out every few seconds that the r.p.m. are incorrect. The impression grows on him that the sole qualification for a helicopter instructor is to be able to shout "revs!" at the right moment.

Full circuit procedure is taught following initial attempts to hover with all the controls. To practise landings and take-offs in a helicopter, circuits are not necessary. Rather is the purpose of a circuit to teach the pupil climbs, descents, turns, straight and level flying, all at the correct power settings and air-speeds; to give him practice in judging the effect of the wind on a slow-moving aircraft; and to give him practice in the general co-ordination of controls and judgement of the approach.

For attaining good control co-ordination, the transition exercise is excellent. Briefly, this consists of a hover at 20ft, followed by a gradual acceleration to about 50 m.p.h. and a deceleration to the hover—all at 20ft. Not only is the exercise good for teaching control co-ordination, but it is a practical demonstration of the following: (1) The tendency to lose height when the stick (and therefore the lift vector) is inclined forward. (2) Gain in translational lift with air-speed. (3) Tendency of the nose to rise, due to the tendency of the rotor to tilt back with forward speed. (4) Variation in fuselage attitude when accelerating and decelerating. (5) Tendency for the r.p.m. to increase as air-speed is increased. (6) Tendency for the r.p.m. to increase while air-speed is being decreased, but with an overall tendency for r.p.m. to be lower at lower air-speed. (7) Loss of translational lift when speed has been decreased—this is most noticeable just prior to the hover. (8) Increase in torque with power.

Transitions are not easy, and the general tendency of pupils on their first attempt is to carry out a continuous climb to 200ft and then come to the hover.

The final batch of exercises prior to solo concern the autorotation sequence. Apart from the obvious importance of these exercises in teaching a pupil what to do in the event of engine failure, they are of great value for attaining good co-ordination of the lever and throttle. This is especially so when entry into autorotation (slowly) and the overshoot procedure (with power on!) is practised, as in this case the lever is moved through almost its full range in each direction while the r.p.m. are kept constant by use of the throttle.

After solo there is another batch of about twenty exercises. They include such obvious things as steep turns, cross-country flying and taxying, and less obvious items such as take-offs and landings on sloping ground, limited-power take-offs and landings, winching, etc. Winching is not so easy as it looks, owing to the change of c.g. of the aircraft as the load is picked up or lowered on to the ground, and it is an excellent means of assessing a pupil's co-ordination and ability to hover.

Taxying is rarely needed in a helicopter, but must be practised nevertheless. On one occasion a pupil was carrying out some solo taxying practice and I saw him moving too fast and then turning too sharply. The aircraft began some strong bouncing oscillations from side to side on the main undercarriage wheels—the phenomenon known as ground resonance. When it had stopped I drove over in my car and asked the pupil what he thought he was doing. He did not appear at all perturbed and

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said that he had merely experienced "some vibration." I then looked at the tail cone and found that the "vibration" had been sufficient to bend it!

Buyers of British helicopters come from all parts of the world, and the problem of training a pupil who speaks no English can be solved in one of two ways: the instructor can speak set phrases of the foreign language which he has previously sorted out by sign language and a dictionary; or the pupil can learn set phrases in English which the instructor will adhere to in the air. I have used the first method with Italian pupils and the second with Japanese. Only once has other than a minor misunderstanding taken place. On that occasion the pupil switched off both magnetos instead of switching from servo to manual control. We were at 800ft at the time and the airfield was right below, so there was no difficulty in selection of a forced-landing site.

As I said at the beginning, the training of helicopter pilots is usually reserved for those with fixed-wing experience. The time which these pilots take to solo averages five hours. Post-solo dual is generally a minimum of four hours, but naturally this side of training must be kept elastic to cope with different capabilities. For the pupil who has never flown fixed-wing aircraft, the time to solo would average about fifteen hours, and basic instruction would have to cover much more thoroughly such items as the control of air-speed with the stick. During the whole of his training and for some time afterwards the *ab initio* pilot would be at a disadvantage compared with the man with fixed-wing experience. The main advantages of having this experience before converting to helicopters may be listed as follows:—

(1) The pupil has *air sense*, a term which covers a lot of things like being acquainted with the medium in which the vehicle is operating, knowledge of air vehicles and a general appreciation of the physical sensations to be experienced during various flight manœuvres.

(2) He has a good judgment of height, an eye for the weather and appreciation of air movement relative to ground movement.

(3) The stick and rudder pedals operate in a similar manner in both types of aircraft, hence movement of these controls is instinctive, although their reactions tend to vary.

The sole argument which can be raised in favour of the selection of a man of no previous flying experience for training on helicopters is that he does not have to "unlearn" anything. But this argument is inadequate, because it takes but a few hours for an experienced fixed-wing pilot to overcome his aeroplane instincts, and previous piloting experience then becomes an enormous asset. A brief list of the main differences which a fixed-wing pilot will find when flying a helicopter can be given as follows:—

(1) There is a time-lag following movement of the stick.

(2) Engine handling is more critical.

(3) The aircraft does not stall and lose control when fuselage air-speed is reduced below a pre-determined figure.

(4) The throttle is not closed when descending; rather is it used to maintain constant r.p.m.

(5) Fuselage attitude does not have such a direct bearing on the flight path.

(6) Power changes, especially at slow air-speeds, necessitate a considerable alteration of the rudder position in order to retain a directional heading.

(7) In the event of engine failure, the pilot must take immediate action to prevent the rotor slowing down dangerously.

Finally, how does one become a helicopter *instructor?* There are various requirements for the issue of instructors' certificates, depending on past experience, but let us take the case of a pilot who has just completed 300 hours' flying as pilot-in-charge on fixed-wing aircraft (without doing any instructional flying), and who has just taken up helicopter work. He must first of all carry out 100 hours' flying as pilot-in-charge on helicopters. He then takes a test from a member of the panel of examiners and, if found satisfactory, is rated as an assistant instructor. For upgrading he must complete a further 100 hours of instructional flying on helicopters and pass a further test. He is then rated as a full instructor.

DE-ICING: A NEW ELECTRICAL APPROACH

WITH the introduction of lightweight generating equipment, the use of electrical surface heaters is now well-established for the protection of aircraft from icing. A new development in this field is the surface-heater element devised by D. Napier and Son, Ltd., the basic arrangement of which is illustrated in the diagrams below.

The requirements for an electric heater mat, as determined by the company, were:—

(1) A high thermal efficiency, i.e., the heat losses to the structure should be at a minimum, and heat transfer to the external surfaces at a maximum; (2) the resistance of the conductor element should be capable of adjustment in the design stage, in order to give any required power loading at any specified voltage over a wide variation of areas; (3) the physical, electrical and mechanical properties of the heater should be unaffected by temperatures from −60 deg C to +70 deg C, and the heater should be non-inflammable; (4) the external surface finish should be aerodynamically smooth and should have a high resistance to abrasion and rain erosion; (5) the mat should be thin; (6) it should be capable of application to any shape of surface, including those of compound curvature; (7) good adhesion to metallic surfaces, and to light alloys in particular, is essential; (8) the insulation material should have low water-absorption properties and be impervious to fuels, oils and hydraulic fluids; (9) it should be possible to carry out local repairs on the heater; (10) its weight per unit area should be a minimum.

These requirements indicated to Napiers that it would be advantageous to fabricate the heater by a spraying process, both for insulation and for the electrical element, directly on to the surface to be protected. Progress along these lines led to the heater mat construction shown below, the base insulation of which consists of a layer of a thermo-setting resin applied by a flame spray-gun. Also applied by a flame spray-gun, the electrical conductor consists of a metallic coating to the resistance and pattern called for by the particular heat distribution required. This coating is provided with suitable terminals for connection with the electrical system. The outer insulation, of similar material to the base layer, is sprayed on and finally finished as a highly polished surface.

The Napier heater mat may be applied to the surface of suitable shapes by mechanical means, which normally take the form of traversing gear linked by a suitable mechanism to the workpiece turntable in such a way that the rate at which the spray-gun passes across the workpiece can be controlled. In general, surfaces of single uniform curvature, of aerofoil section, and of spinner section, can be treated by mechanical methods, while for more complex shapes a combination of hand and mechanical methods is normally used.

Diagrammatic section through the heater mat as applied to a surface.

The method makes possible a very light heater mat. The total thickness is from 0.040in to 0.050in, depending on the conductor thickness, and the corresponding specific weight is 0.26 to 0.32 lb/sq ft. A comprehensive series of tests has been carried out on the equipment, including those for vibration, electrical insulation, inflammability, endurance, fatigue, and general serviceability. The maximum operating temperature for the mat is at present stated to be 100 deg C, and overheat protection (in the form of a thermal cut-out utilizing a resistance sensing-element) has been devised.

Assembly of a terminal block, showing how contact is made with the metallic coating.

The electro-thermal method of ice protection, and in particular the Napier surface heater method, can be used both for continuous anti-icing and for cyclic de-icing, a typical cyclic ratio of "heat on" to "heat off" time being 1:10 for, say, mainplane, tailplane, and fin leading edges. An advantage of the Napier construction is the ease with which electrical repairs can be carried out, if necessary, by hand spraying.

At present, examples of the Napier heater-mat installations in production include the fin leading edge of the Bristol Britannia, the engine and oil-cooler intake for the Short Seamew, the combustion-heater air intake on the Elizabethan, and the engine air intake on the Fairey Gannet. The compound curvature involved in these parts make the electro-thermal method of protection, compared with either hot gas methods or mechanical methods, the most suitable installation.

ROTORS over the JUNGLE

No. 848 Naval Air Squadron in Malaya

By Lt-Cdr. J. E. BREESE, R.N.

JUNGLE warfare against terrorists poses problems not to be found in the older military text-books, and to many of these, within the past year or two, the helicopter has provided an ideal solution. Wanting to tell readers more about such operations, we invited Lt-Cdr. Breese, a pilot of No. 848 Sqn., to give some first-hand impressions. His article—published with Admiralty approval—appears below. Since it was written, the Admiralty have provided these latest figures for No. 848's work in Malaya: Flying time, 4,004 hours 45 minutes; troops lifted, 11,791; freight lifted, 201,680 lb; casualties evacuated, 314.

NO. 848 SQUADRON, the Royal Navy's first operational helicopter unit, was formed at the end of October 1952. In just over two months it became land-based in Malaya for operations over the jungle.

I was appointed to the squadron on its formation and stayed with it until December last. During that time we flew over 3,500 hours, lifted between 10,000 and 11,000 troops into and out of the jungle and evacuated 275 casualties. We also carried out miscellaneous tasks which included supply dropping, reconnaissance and target-marking. The squadron was equipped with ten Sikorsky S-55 helicopters, a large range of spares and comprehensive ground equipment, supplied by the United States under the Mutual Aid programme.

We sailed from Portsmouth in H.M.S. *Perseus* on December 12th, 1952, and on January 8th, 1953, when near Changi point, flew-off the aircraft to the Royal Naval Air Station at Sembawang on Singapore Island.

We soon had our first incident, one of the aircraft forced landing in a clearing on the Federation side of the Johore Straits because its tail-rotor control had become jammed. With one aircraft detached to maintain guard, the rest proceeded Sembawang. Here the squadron A.E.O. was embarked in a winch aircraft and was soon being winched down into the clearing where the S-55 had landed. The trouble, due to a "proud" bolt in the rear control pulley, was soon located and rectified, and within two hours the helicopter arrived at Sembawang.

Now began a period of intensive training for the task ahead. It appeared likely that our most exacting flying would be into and out of jungle clearings, so it was decided to concentrate the training on work of this kind. First, a circle 50ft in diameter was marked on the airfield, into which vertical descents from 200ft were made. Next, a similar area was cleared in some 80ft rubber trees on the edge of the airfield and, lightly laden, the aircraft were taken into that. With familiarity came increasing confidence, both in the helicopters and in ourselves, and in a short time we were taking in maximum loads.

Our thoughts now turned to the final test, descents into 200ft-high primary jungle. There was none available for our use on Singapore Island, but the Army, who had a jungle training school in Johore, readily agreed to cut a clearing for us there. This was soon ready, and daily we flew across the Johore Straits and into the clearing.

On January 21st three aircraft were detached to R.A.F. Kuala Lumpur to carry out trials which included aircraft performance, methods and equipment for the emplaning and deplaning of troops, supply dropping, use of the external sling and winching of casualties. Later, in conjunction with the R.A.F., methods of vegetation-spraying were evolved.

Officers of No. 848 Squadron relax in a primitive jungle shelter during an interval in a troop-lifting operation. Left to right: Lt-Cdr. S. H. Suthers, D.S.C., Lt. J. Walden, and the author.

Towards the end of January we were given our first operational task, a casualty evacuation, and from then the work started to come in. On February 2nd, with the trials completed, we gave a grand demonstration of our capabilities to representatives of the Army and the Police. From then on the flow of work increased until by the end of March it had become a flood. The aircraft were behaving magnificently, and it now became obvious that, if we intended to work the aircraft to their maximum capacity—and the jobs in hand demanded that we should—we required additional pilots. Approval was soon given for them to be flown out from the United Kingdom.

We still had only three helicopters based on Kuala Lumpur, the other three and the four reserves being at Sembawang; but now that the pattern of operations was becoming clear it showed the need to concentrate all six operational machines at Kuala Lumpur. This was accordingly effected.

There was no hangar accommodation at Kuala Lumpur, so the aircraft were out in all weathers. In spite of this, serviceability remained high. It invariably rained overnight, and one got into the habit of raising the collective-pitch lever before starting in order to drain the water from the rotor blades. Then, after priming, two to four seconds on the starter were enough to get the engine running. This easy starting saved us what would have become endless battery trouble, for, as trolley accumulators were available only at Kuala Lumpur and Sembawang, 90 per cent of all starts had to be made on the aircraft batteries.

The reliability, lightness of control and good manœuvrability of the S-55 makes it most suitable for operation in Malaya. Though experiencing the usual stability deficiencies of helicopters, one could nevertheless be quite relaxed when at the controls. The performance, taking into account the high temperature and humidity experienced in Malaya, tallied with the estimated performance given in the makers' handbook. The fact that the fuel tanks are under the hold, thus allowing the filler caps to be at a convenient level, proved to be a great advantage, as fuelling was invariably from 50-gallon drums, *via* a four-gallon tin and special chamois filter. One great disadvantage, however, is that there is only 10½in clearance under the rear of the fuselage. Without detriment to their anti-ground-resonance properties we increased the pressure in the main oleos, thus improving this ground clearance a little, and at the same time lifting the tail rotor a trifle higher.

Except when looking across the cockpit, downward and forward view in the S-55 is extremely good, so it was necessary to carry an observer as a lookout only for the more difficult clearings. The fact that an observer up in front meant one less soldier in the hold always had to be faced. When troop-lifting, therefore, only the leading aircraft carried an observer. Having navigated to and identified the clearing, he would, if necessary, deplane with the troops in order to supervise the work of improving the clearing. If that was not necessary he deplaned at the end of the first sortie and employed himself in lining-up the troops for emplaning and in supervising the refuelling. On a big lift, when relief pilots were available, he would run the pilots' roster in addition. Fuelling usually took place every second or third sortie, and as it took only about four minutes the reliefs had to be on top line to avoid delay.

Although at first one bit of jungle looks the same as any other, the pilots soon learned to note small features and, having once been to a clearing, could invariably find it again without the aid of an observer and without reference to the one-inch map.

For casualty evacuations an observer was always carried. These operations were invariably from hastily cut clearings; and the observer, apart from his value as navigator, proved invaluable as a lookout for his side of the aircraft and for the tail rotor. If

ROTORS OVER THE JUNGLE . . .

winching was necessary he tipped up his seat, climbed down into the hold and operated the winch control from there.

Casualty evacuations were the most satisfying of all operations, because here the helicopter was essential. Frequently a ten-minute lift by us saved a gravely injured man five days of being carried through the jungle—probably the difference between life and death. On the other hand, troop-lifting was the most interesting type of operation, as one could carry-in the troops and then follow their progress from a distance. Troop-lifting was always a mad rush, with split-second timing, in order to get the men into the clearing as quickly as possible. Sortie after sortie would be flown, until eventually one lost count.

One of the most interesting troop-lifts in which I took part was carried out in July. I was detached to attend briefing for an operation to be mounted the following day, and the intelligence, as I remember it, was something like this: An Auster pilot of an A.O.P. flight had reported finding Communist Terrorist cultivation in deep jungle, and from other information it seemed probable that there was a camp in the vicinity. The object of the operation was to attack the camp, if found, and to destroy the crops. The troops would be lifted by helicopter to a position about four miles from the cultivation. From this position they would make a reconnaissance and then attack the camp at dawn the following day. The Auster pilot had also reported that there was a small natural clearing, on the bend of a river, at a suitable distance from the cultivation. Owing to the height at which the reconnaissance had been carried out, he could not be sure that the clearing was entirely suitable, as tall trees overhung it on each side. Our instructions were to put the troops into the clearing as quickly as possible or, if the clearing was not suitable, to put them as near to that position as possible. Hoping for the best, but fearing the worst, we decided to take three aircraft, two of which were fitted with winches, and to position them at the emplaning point that afternoon, as fog was expected to cover the area first thing in the morning.

How the winch-sling of the S-55 is used. In situations where the helicopter can descend to within about 20ft of the ground, a knotted scrambling-rope may be used instead of the winch.

With ground crews and equipment and our overnight bags aboard, we were airborne from Kuala Lumpur soon after lunch. Arriving at our destination, we prepared the helicopters for the following day's programme. Then, as the troops were available, we exercised them in emplaning and deplaning drill. By now it was dusk and we dispersed to our quarters, for some an *attap* (palm leaf) hut and others a tent. After dinner that night we were able to discuss the coming operation with the Auster pilot who had made the reconnaissance and with the company commander of the troops being lifted in.

The next morning at take-off time, sure enough the fog was there; and our fighter escort of Hornets, with whom we were in touch, reported that the whole area was covered by low cloud. They had enough fuel to enable them to stay on their patrol line for a further hour. By 0900 the cloud had lifted sufficiently for us to get airborne. Flying at 200ft above the jungle in loose line astern we soon reached the clearing, and here our worst fears were realized. It might have done for a once-only casualty evacuation, but it was definitely unsuitable for a troop lift. Nearby, however, was a patch of secondary jungle with trees only 75ft high, so we decided to winch the troops into that. After our talk with the Auster pilot the previous evening we had anticipated the need to winch-down the men while hovering outside the ground cushion and had accordingly reduced the number of troops carried in the winch aircraft for the first sortie.

Sending the third aircraft back to the emplaning point, we hovered in turn over the selected spot and, one at a time, down through the trees went the troops. At times they disappeared from the view of the winch operator, but he carried on lowering, and fortunately no one got hung up.

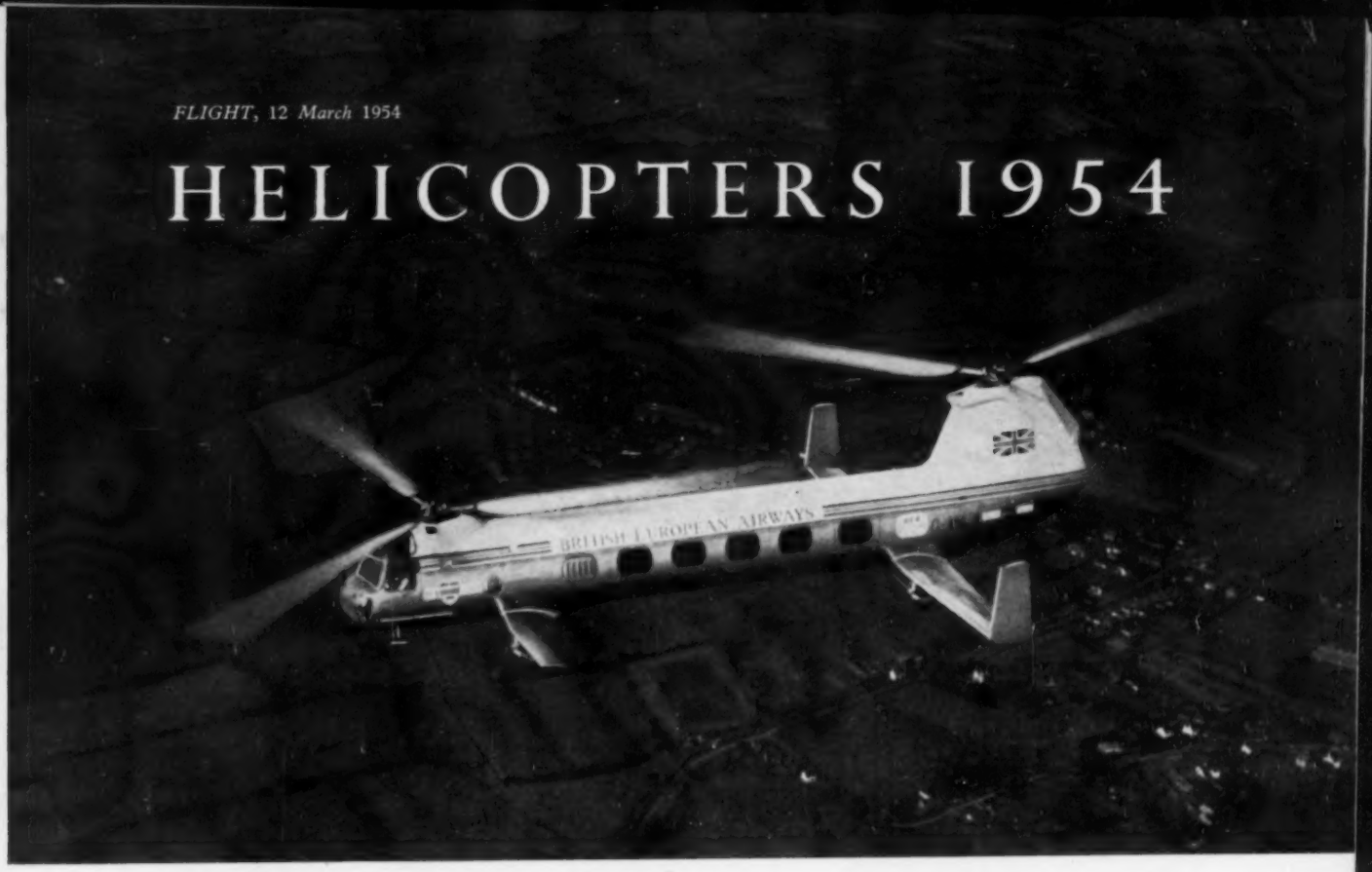
As soon as the first troops were in the clearing, the Hornets were dismissed; we had heard them on the radio, but had not once seen them. Now began a race back to the emplaning point and then off to the embryo clearing, where the first troops in had already made an impression on the jungle with their parangs (Malayan knives). By the next sortie the clearing was large enough to go in and hover at about 18ft, thus allowing the troops to drop from the ends of the scrambling ropes. Our worst troubles over, we could now increase our load and, with the assistance of the third aircraft, the lift would proceed apace.

Back at base we disembarked the observers, who had now completed their job in the air, allowing yet another soldier to be carried into the clearing by each S-55. On arrival we found there was now sufficient ground cleared for the helicopters to touch down, so from then on the troops deplaned in the normal way. By 1400 hours the lift was completed, and we were all enjoying a quick lunch while the aircraft were being refuelled and greased preparatory to flying back to Kuala Lumpur.

So, for us, ended a most interesting operation; but for the troops it had only just begun. Already they were making their reconnaissance and could be certain of staying in the jungle for from five to ten days. Then, if they were urgently required for another operation, they might be lifted out. If not, they would have to walk, so great is the demand for the services of the helicopters.

This typical landing zone, cut in bamboo, was first used for casualty evacuation; it was later improved by the building of a platform. The man by the felled tree gives scale. Below is a troops'-eye view of the same clearing, with one of No. 848's S-55s among the bamboo.

HELICOPTERS 1954



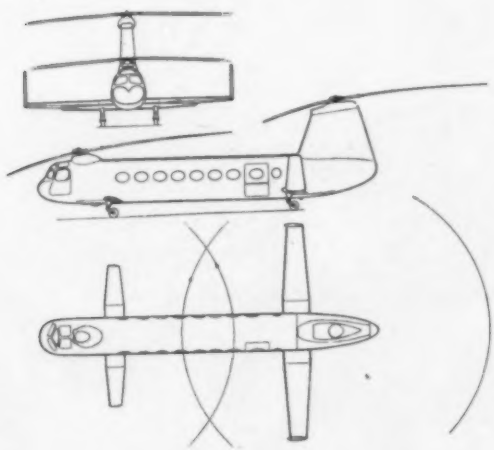
Bristol Type 173 Mk 2.

LITTLE more than a year has passed since the helicopters of the world were last reviewed in this journal, and though nothing in the nature of a metamorphosis has since been witnessed, it is certainly true that projects of the highest significance have been realized in the meantime. Of these, the Piasecki XH-16, Sikorsky S-56 (XHR2S) and McDonnell XV-1 are especially notable, for they signpost the roads towards increased capacity, improved performance (particularly in speed) and greater safety.

Because these designs are American it must not be supposed that technical progress in Great Britain has been negligible; on the contrary, our leading makers are pursuing their individual researches along clearly promising lines, as references to the Fairey Rotodyne, Percival P.74 and other developments will testify. Of more immediate interest and importance is the winged (Mk 3) version of the Bristol 173, now under construction for British European Airways, and the anglicized, Westland-built development of America's Sikorsky S-55. France merits reference for her characteristically venturesome little S.O. Djinn, with its blade-tip, compressed-air jets, and for the Farfadet "gyrodyne," distinguished by its turboprop and jet-driven rotor.

Clearly marked by such machines as Bell's anti-submarine XHSL-1 is the trend towards specialization, particularly for military purposes; but, regardless of size or performance, all current helicopters are eminently versatile, and even the older designs will, for many years yet, render invaluable service in the most exacting circumstances.

Bristol Type 173 Mk 3.

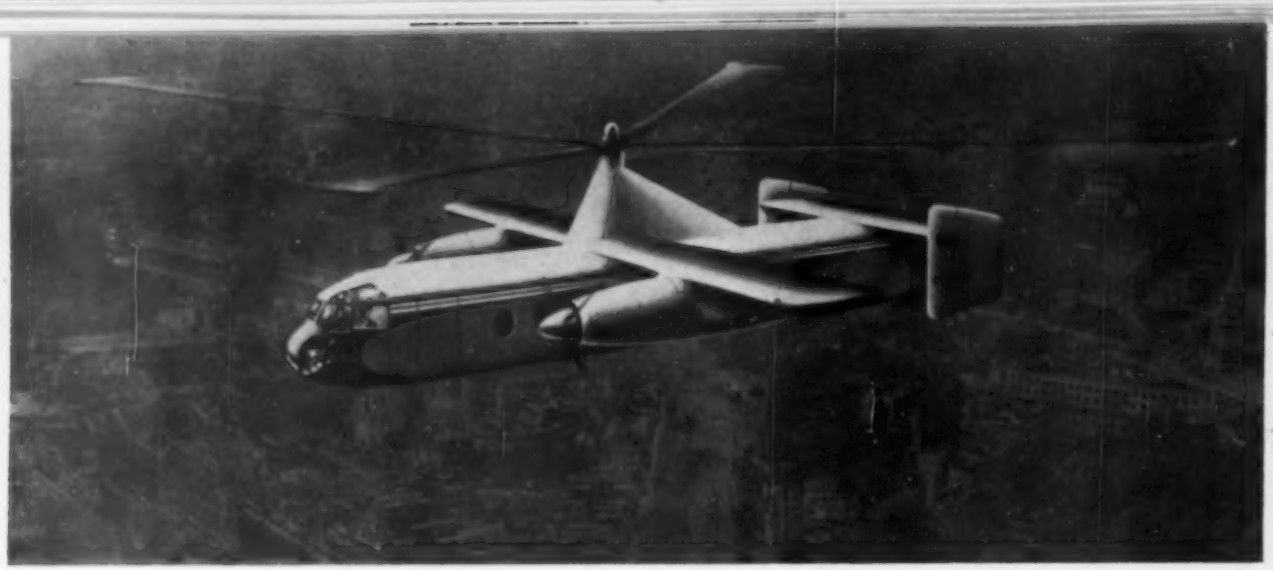


WEIGHTS ABOVE 6000 lb

BRISTOL TYPE 173 • The three variants of this twin-rotor helicopter announced to date are identified thus: Mk 1, the first prototype, with provision for 10/13 passengers and powered with two Alvis Leonides Mk 73 engines; Mk 2, the second prototype, essentially similar to the Mk 1, but modified to explore the characteristics and effects of stub wings; Mk 3, a winged, 16-seater development, with Alvis Leonides Major engines. Three Mk 3s are under construction for experimental service with British European Airways, and the following description and data apply to that variant.

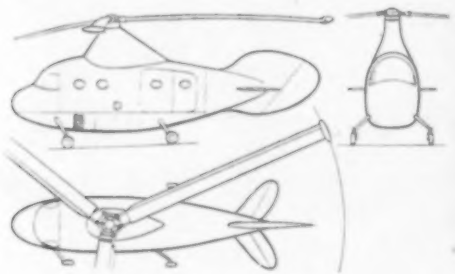
The two 850 h.p. Alvis Leonides Major engines are installed one at each end of the fuselage, below the opposite-rotating, Sycamore-type rotors. The individual rotor gear-boxes are connected by a synchronizing shaft running along the roof of the fuselage; this ensures that both rotors turn at the same speed, and permits one engine to drive both rotors if the other engine should fail. A free-wheel in the drive system from each engine to its nearest rotor allows isolation of a dead engine, or full autorotation with both engines out. Each engine is housed in a steel cowling, in the form of a fireproof box, and the power-plant bays are isolated from the cabin by soundproof bulkheads. As on the Sycamore, the rotors have a high moment of inertia and are run at high r.p.m. so that sufficient kinetic energy is stored in them to permit a safe landing even if both engines should fail.

The main portion of the fuselage is of ovoid section and of



Fairey Rotodyne—a new drawing, showing latest configuration.

Helicopters 1954 . . .



Percival P.74.

Model of Percival P.74.

conventional light-alloy semi-monocoque construction. Twelve of the 16 passengers have individual seats, and the other four share a bench-type seat. In the place of two of these bench-seated passengers a toilet can be installed. Provision is made for a stewardess. As a freighter the Type 173 Mk 3 will carry 3,000 lb as a distributed load, or 2,200 lb as a concentrated load —in which connection it may be noted that the four-wheel undercarriage ensures a level platform, and that the low floor-level and large door (5ft high × 3ft 7in wide) greatly facilitate loading.

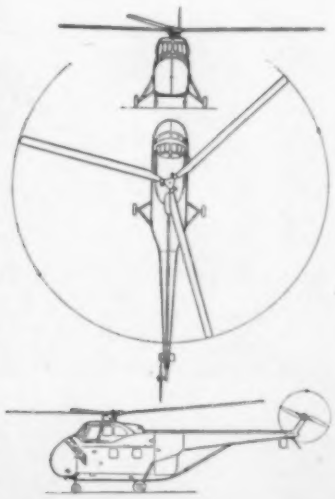
Leading data: rotor diam., 48ft 6.7in; overall length (blades folded), 54ft 1.7in; span of front wing, 21ft 3in; span of rear wing, 33ft; min. rotor clearance above ground, 7ft; cabin length, 28ft 8.7in; cabin height (in gangway), 5ft 8.5in; cabin width (max.), 5ft 2in; cargo space, 660 cu ft; all-up weight (single-engine climb condition), 13,500 lb; all-up weight (max.), 14,500 lb; disc loading (at 13,500 lb), 3.63 lb/sq ft; power loading (1 hr rating), 7.95 lb/h.p.; max. design level speed, 153 m.p.h.; max. weak-mixture cruising speed, 138 m.p.h.; max. rate of climb at 75 m.p.h., 2,000ft/min; max. single-engine rate of climb at 75 m.p.h., 100ft/min; hovering ceiling outside ground cushion, 7,400ft; service ceiling, 16,000ft; still-air range (14 passengers with 25 lb of luggage each, toilet and stewardess), 182 statute miles. (N.B. All performance figures are estimated.)

BRISTOL TYPE 181 • Under this designation the Bristol company has designed a very large twin-rotor helicopter, intended primarily for commercial operation and, it is believed, using the Type 173 tandem-rotor formula. Gas turbine power plants would appear to be a logical choice for such an ambitious aircraft.

FAIREY ROTODYNE • When announcing that a Rotodyne had been ordered for research purposes by the Ministry of Supply, the Fairey company stated that this machine would be powered with two Napier Eland turboprop units of 3,150 h.p. each, and would use the Fairey patented system of tip-driven jet rotors. The real significance of the design, it was claimed, was that it would be the first rotary-wing aircraft to challenge the D.C.3.

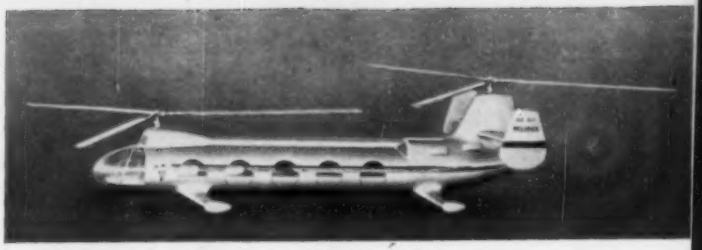
The layout of the Rotodyne is shown in the drawing herewith. The single main rotor has four blades and measures 90ft in diameter; the fixed wing is of 46ft 6in span. Capacity is quoted as 40 passengers with baggage, and the economical cruising speed

(Below and bottom right) Westland-Sikorsky S-55.

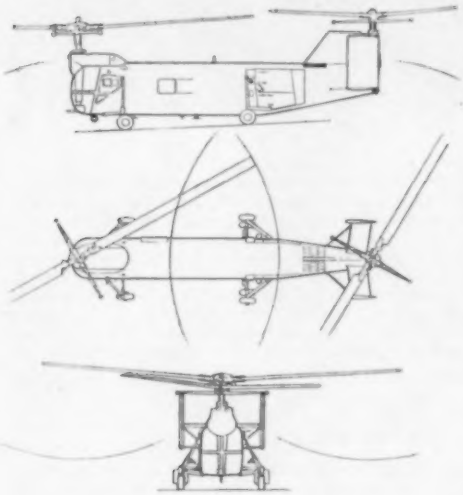


as "not less than 150 m.p.h." The still-air range is stated to be about 250 nautical miles, and the operating cost 3d per seat-mile at 100 nautical miles (utilization 2,500 hr p.a., 30 knot headwind, 25 min diversion).

PERCIVAL P.74 • Now under construction for the Ministry of Supply, this eight-passenger helicopter is powered with a Napier high-efficiency, low-pressure, gas-propulsion system which is claimed to avoid all mechanical couplings between the source of power and the rotor. Air ducts feed up on each side of the cabin, the forward part of which has four forward-facing seats and the aft part four rearward-facing seats. The rotor has three blades and is rotated by tip-mounted jets. The makers state that the elimination of the usual cooling arrangements and complicated transmission system will greatly reduce the maintenance and overhaul times. Another feature of the drive, they say, is that it is the quietest available, and they estimate that the noise level will be of the order of 90 decibels at a distance of 100ft and 70 decibels in the cabin. The gross weight is quoted as 7,750 lb and the cruising speed as 120 m.p.h.

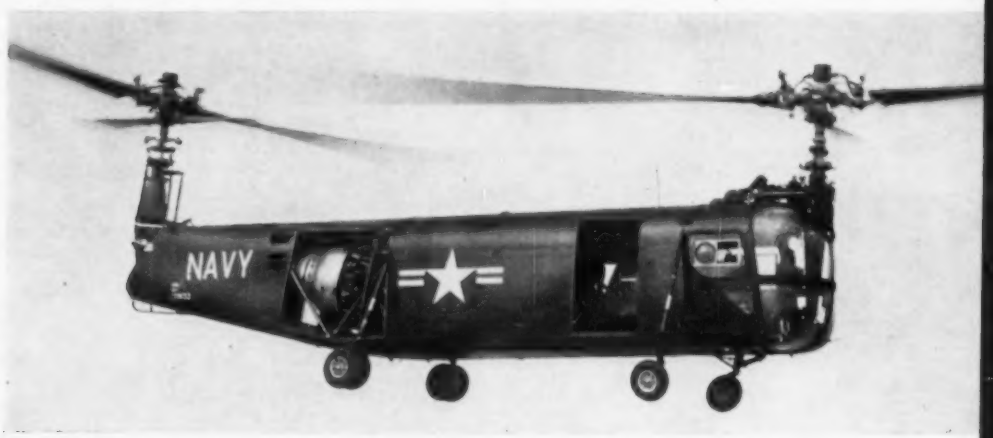


Model of S.E. Helibus.

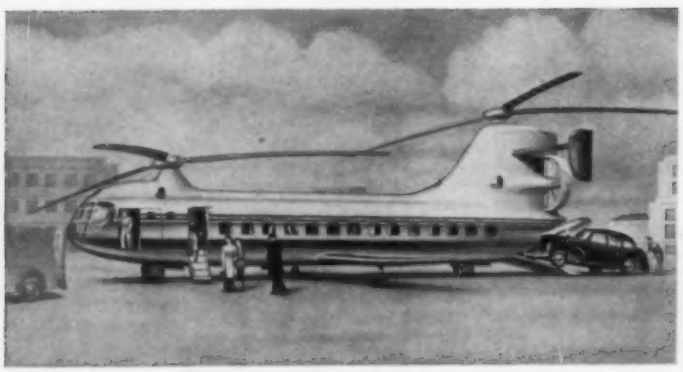


Russian helicopter (S-55 type).

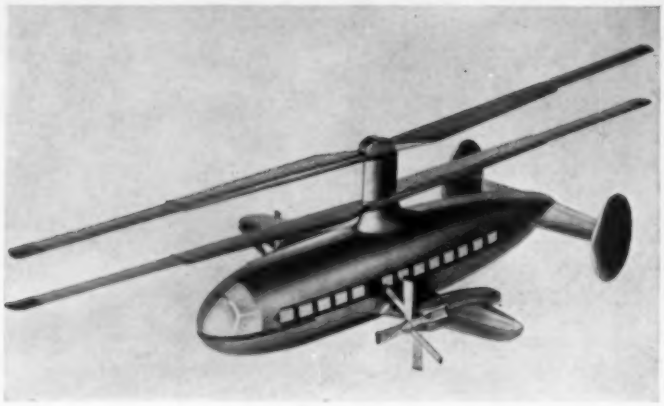
(Drawing above and picture right) Bell HSL-1.



(Below) Saunders-Roe project.



SAUNDERS-ROE PROJECT • In releasing the first artist's impressions of this aircraft last summer (one of these is reproduced on this page) Saunders-Roe, Ltd., gave little information beyond what could be gathered visually. It will be seen that the design—to the requirements of British European Airways—is characterized by tandem rotors; small wing; tandem main undercarriage, with outrigger wheels beneath the wings; a horizontal tailplane and a ten-blade pusher propeller at the stern. The diameter of the power plant exhausts, one of which is visible at each end of the aircraft, suggests gas-turbine power, and it will be noted that the rotor heads are very cleanly faired in. Note also that the rear loading door is large enough to admit a fair-size



Gyrodyne Model 24.

(Right) Gyrodyne Model 35.

Helicopters 1954 . . .

car. Upwards of fifty passengers would be carried for ranges greater than 100 miles.

WESTLAND-SIKORSKY S-55 (WHIRLWIND) • As now in full production at the works of Westland Aircraft, Ltd., the S-55 is being offered with a choice of three power plants, one British and two American. The British unit is the new 14-cylinder Alvis Leonides Major of 800 h.p., and will become the standard power plant; alternatives are the Wright R-1300 Cyclone, a seven-cylinder radial, likewise of some 800 h.p., and the Pratt and Whitney Wasp R-1340, a nine-cylinder unit of 600 h.p. This last-named engine has hitherto been generally installed in the American-built S-55s.

Some measure of the efficiency of the S-55 design is the fact that, although it has three times the load-carrying capacity of the earlier S-51, its overall dimensions are very little larger; the rotor diameter—at 53ft—is only 4ft more, and the overall height only a few inches greater.

In the construction of the semi-monocoque fuselage magnesium alloys are used to a very great extent. The engine and its accessories are mounted in the nose rather than on the centre of gravity, as in the S-51, and access is gained through two non-structural nose doors which fold back on vertical hinges.

The dual-control cockpit is located high up above, and slightly behind, the engine. Arrangement of the main cabin around the centre of gravity and at a low level allows variations in loading without affecting the balance of the machine. Each of the four undercarriage wheels has individual hydraulic shock-absorption; the two nosewheels are fully castering and self-centring, and a skid protects the tail rotor in case of tail-down landings. All-metal amphibious flotation gear can be fitted if required. The normal fuel supply is 150 gallons, affording a range of about 400 nautical miles, but additional fuel and oil can be carried in auxiliary tanks and S-55s have already demonstrated a ferry range with these fitments of 1,000 miles.

Leading data: rotor diam., 53ft; fuselage length, 42ft 2in; empty weight (including utility soundproofing and cabin heater), 4,833 lb; all-up weight, 7,200 lb; max. speed (take-off rating), 108 m.p.h. at 199 rotor r.p.m.; max. weak mixture cruising speed, 86 m.p.h. at 186 rotor r.p.m.; best rate of climb (max. continuous output), 680ft/min at 57 m.p.h.; max.-endurance air speed, 57 m.p.h.; range (150 gal), 330 nautical miles; service ceiling, 11,000ft; hovering ceiling, 5,100ft.

S.E. HELIBUS • This 30-passenger project by the Société Nationale de Constructions Aéronautiques du Sud-Est would be powered with two turbines and utilize S-55 rotors and rotor heads. (The company holds the manufacturing licence for the S-55, which it has dubbed the Joyeux Eléphant.)

RUSSIAN HELICOPTER (S-55 TYPE) • Just as the Russians were quick to produce a helicopter modelled along S-51/Bristol Sycamore lines, so, during 1953, appeared a later, larger machine evidently patterned on the Sikorsky S-55. One of the very few available photographs is reproduced herewith, and little can be added to what can be gathered from a study of this picture.

BELL MODEL 61 (HSL-1) • The first helicopter to be specifically designed for anti-submarine work with the U.S. Navy, the HSL-1 is now in production at Fort Worth, Texas. Carrying detection and destruction equipment, it will serve both in the "hunter" and "killer" rôles. The makers point out that the machine differs from the normal concept of helicopter configuration in that its fuselage is much smaller than its engine—a Pratt and Whitney Double Wasp—would support. They add that the present power plant and rotor system have sufficient reserve to sustain a transport version with a much larger fuselage without compromise in safety. The reason for the relatively small fuselage of the present type is the necessity for below-deck stowage aboard aircraft carriers, and the same consideration dictated that the rotor blades should be arranged to fold. Because of its high degree of inherent stability, in combination with an automatic pilot developed by Bell, the HSL is fully capable of all-weather operation. Unofficially it is stated that it carries search radar, "dunking" sonobuoys, and over 4,000 lb of anti-submarine stores.

BELL MODEL 200 (XV-3) • Little is known about this military project for a convertiplane, but it is believed to be fitted with a Pratt and Whitney Double Wasp engine of some 2,300 h.p. and to utilize the tilting-rotor principle.

CONVERTAWINGS MODEL E • A projected tandem-winged, four-rotor, turbine-powered, short-haul helicopter—one of a series of machines of this layout proposed by Convertawings, Inc.

GYRODYNE MODEL 24 • This is a project for a cargo helicopter of co-axial configuration, powered by twin turboprops with a combined output of 7,000 h.p. The crew would number three and, as the accompanying drawing shows, the machine would have a detachable cargo pack. Provisional data are: rotor diam. 110ft; empty weight, 21,630 lb; gross weight, 70,000 lb; max. speed at s.l., 116 m.p.h.; cruising speed at s.l., 90 m.p.h.; max. rate of climb at s.l., 1,000 ft/min.

GYRODYNE MODEL 35 • Designed as a high-speed transport convertiplane, the Gyroliner, as this project is styled by the makers, would be powered, like the Model 24, with two turboprops. Seventy-two passengers and a crew of three would be carried in the streamlined fuselage and, as the photograph of the model shows, the counter-rotating rotors would each have only two blades. Provisional figures are: rotor diam., 88ft; gross weight, 77,500 lb; max. speed at s.l., 304 m.p.h.; cruising speed at s.l., 230 m.p.h.; max rate of climb at s.l., 2,350 ft/min; range, 500 miles.

HUGHES XH-17 • With its single two-blade rotor measuring over 125ft in diameter, the XH-17 is the world's largest helicopter of its configuration and, though little or nothing has been heard of it for many months past, it again figures in our review as an important milestone in the development of rotary-wing aircraft. Power is supplied by two General Electric J35 turbojets, which deliver gas pressure through ducts leading up the rotor shaft to feed tip-mounted GE33F burners. A tail rotor, shaft-driven from the main rotor, is fitted, and a tailplane allows considerable c.g. travel.

The XH-17 is classed as a "heavy-lift" helicopter and its 27,000 lb payload is intended to be slung beneath the central nacelle; it might comprise such equipment as field artillery, sections of bridges and M.T. vehicles. The gross weight has been unofficially stated as 52,000 lb, max. speed 80 m.p.h., cruising speed 40 m.p.h., and range 40 miles.

McDONNELL MODEL 78 (XHRH-1) • This large assault transport for the U.S. Marine Corps has been under development since 1951. It has gas turbine power.

McDONNELL MODEL 86 (XCH-1) • Intended as a "flying crane" for use by the U.S. Marine Corps, this machine will probably have a single large rotor, with McDonnell tip drive.

PIASECKI PD-22 WORK-HORSE (H-21) • There are

Hughes XH-17.

four variants of this large tandem-rotor, single-engined helicopter—the YH-21, H-21A, H-21B and H-21C. The YH-21 and H-21A are 16-seaters, designed specifically for arctic rescue work. The cabin will accommodate 12 stretchers or 14 troop seats, and inflatable flotation gear permits landing on all types of terrain. Both machines are powered by the Wright R-1820-103 which, though it has a take-off rating of 1,425 h.p., is derated to 1,150 h.p., as this power is adequate for the prescribed missions. The fuselage is of all-metal, stressed-skin construction, and the cockpit has side-by-side seating with complete dual controls and an automatic pilot. Cabin dimensions are 20ft long × 5ft 6in wide × 5ft 6in high, giving a capacity of 615 cu ft. The main door is on the left side at the aft end, and there is a rescue door, with a swinging boom-like hoist, behind the pilot at the forward end. Complete winterization equipment, including cabin heating and insulation, is standard.

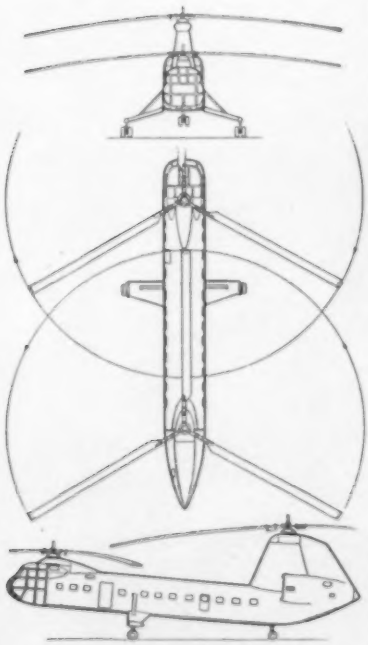
The H-21B is an assault transport for the U.S.A.F., with seats for 20/22 troops, a larger rear door and extra windows. The H-21C is a supply transport for the U.S. Army, though it is capable of being used alternatively as a troop carrier.

The following data apply to the YH-21 and H-21A: rotor diam. 44ft; fuselage length, 52ft 6in; fuselage height, 16ft; fuel capacity, 300 gal; power loading, 10 lb/h.p.; weight empty, 8,500 lb approx.; normal gross weight, 11,500 approx.; overload gross weight, more than 14,000 lb; max. speed at s.l., 130/140 m.p.h.; service ceiling about 17,000ft; range, over 500 miles.

PIASECKI PV-15 TRANSPORTER (YH-16) • This typical Piasecki design is the largest helicopter in the world, measuring 134ft overall and standing 25ft high. The fuselage is

(Right) Piasecki H-21.

(Drawing below and picture bottom right) Piasecki YH-16.



Sikorsky S-55.

port for U.S. Marine Corps; HRS-4, Wright R-1820 engine, assault transport for U.S. Marine Corps.

SIKORSKY S-56 (XHR2S) • The XHR2S is an assault helicopter for the U.S. Marine Corps and is a twin-engined, single-rotor machine comparable in size to the Douglas Dakota. It is the first helicopter in the world to have a retractable undercarriage. The engines are Pratt and Whitney R-2800 Double Wasps, and they are mounted outboard of the fuselage on stub wings; power from both is transmitted to the five-blade main rotor and to the tail rotor, each of which folds for stowage aboard aircraft carriers. The fuselage has nose-opening doors and will carry two combat assault squads, i.e., about 26 fully equipped men. Speed is "over 150 m.p.h."

(Above and bottom right) Sikorsky XHR2S.

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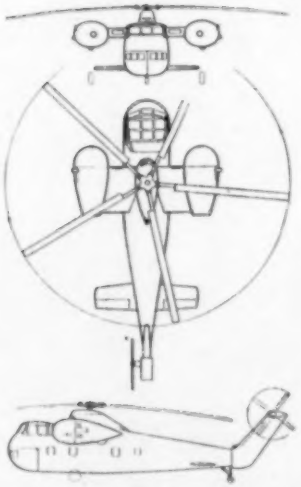
nearly 78ft long—about the size of a Convair 240's—and has capacity for 40 troops, 32 stretcher patients or three jeeps. Whereas the former Piasecki twin-rotor helicopters had only a single engine, the YH-16 is powered with two Pratt and Whitney R-2180 units of 1,650 h.p. each. A later version, designated YH-16A, will have two Allison turboprops of the T38 class. Estimated performance figures have not been divulged, but the speed will be higher than that of the H-21, which last year set up a world speed record of 146.7 m.p.h. Provision is made for a cargo "pack" to be slung beneath the fuselage, and when this is fitted a special tall undercarriage, which raises the fuselage about 10ft off the ground, is required.

In addition to the normal door at the forward end of the cabin, the YH-16 has a ramp at the rear which can be lowered for the fast loading and unloading of vehicles, guns, cargo, personnel or patients. Outside the forward cabin door is a cable hoist, operated by the pilot.

Versions of the turbine-powered YH-16 will be laid out for commercial service and will seat from 48 to 72 passengers.

It is said to be possible in the YH-16 to place the load anywhere in the cabin, for the machine has a larger centre of gravity travel than any other aircraft, including the Brabazon-size Convair B-36 bomber.

SIKORSKY S-55 • The basic S-55 has already been fully described under Westland-Sikorsky, but it must be noted here that the American parent company is continuing to turn out this machine for a variety of purposes. The principal variants are: H-19A, Pratt and Whitney R-1340-57 engine, troop carrier or ambulance for the U.S.A.F.; H-19B, Wright R-1300-3 engine, for similar duties with the U.S.A.F.; H-19C, as H-19A but for the U.S. Army; H-19D, as H-19B but for the U.S. Army; HO4S-1 and -2, Pratt and Whitney R-1340 engine, for anti-submarine work with the U.S. Navy; HO4S-2G, similar to HO4S-2 but fitted for Coastguard rescue duties; HO4S-3, Wright R-1300 engine, for anti-submarine duties with the U.S. Navy; HRS-1 and -2, Pratt and Whitney R-1340 engine, assault transport for U.S. Marine Corps; HRS-3, Wright R-1300 engine, assault trans-



Unofficially it is reported that the rotor is designed to retain a high measure of efficiency should one blade be shot away, and the tailplane should make for added stability. The assault version has nylon flak curtains and can carry, as an alternative to its load of troops, a 105 mm gun or 5,500 lb of cargo. Commercial developments are foreseen and should lift up to 35 passengers over ranges of more than 200 miles.

SIKORSKY S-58 • A development of the S-55, this machine will be available as a 20-passenger civil aircraft (or a freighter carrying 1½ tons), or in various military forms. The U.S. Navy version will be designated HSS-1 and will be used for anti-submarine work. In the U.S. Army it will be known as the H-34 and in the U.S. Marine Corps as the HUS-1.

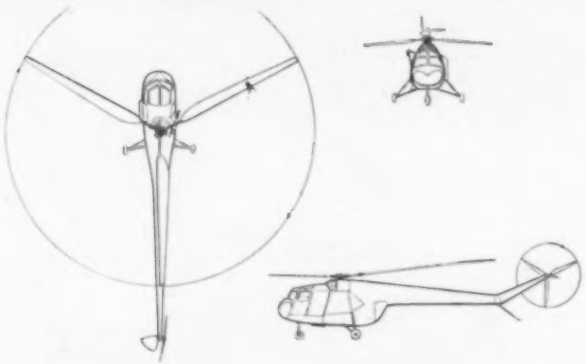
WEIGHTS
2,500 lb—6,000 lb

Fairey Jet Gyrodyne.

BRISTOL TYPE 171 (SYCAMORE) • Since its first flight in 1947 the Type 171 has appeared in numerous forms, notable among which are the Mk 3A, for passenger service with British European Airways and having a greater luggage space than its predecessors; the Mk 4, which is the current production version for passenger and freight work and is capable of rapid conversion for several other duties; the H.C.10, an ambulance with accommodation for two stretchers athwartships; the H.C.11, for transport and observation with the British Army; the H.R.12, for search and rescue and communications flying with R.A.F. Coastal Command; the H.R.13, for similar duties with Fighter Command; and the H.R.50, again for similar duties, but with the Royal Australian Navy. The following notes concern the 171 Mk 4.

The all-metal fuselage embodies the cabin and an engine compartment directly beneath the main rotor, and the tail portion, which supports the tail rotor and houses the fuel tank and luggage compartment. The power unit, an Alvis Leonides 73, is mounted with the crankshaft vertical, and has a cooling fan which draws air through an intake above the cabin.

In the ambulance rôle the passenger's seat beside the pilot is fitted to face aft, for the use of the medical attendant; or if required a swivel seat can be provided. Between the door pillars and the rear bulkhead are bars fitted with quick-release clamps, allowing two special folding stretchers to be secured in position. Blood transfusion equipment is installed. If passengers are to be carried on the outward flight, stretchers can be folded and stowed in the luggage compartment, and three canvas deckchair seats attached against the rear bulkhead. For ordinary passenger and communication flying a seat is installed beside the pilot's and a fully upholstered bench-type seat is fitted along the rear bulkhead. Quickly attachable soundproofing is added and a carpet laid. The doors have Perspex lifters to accommodate the stretcher-ends.



(Above and below) Bristol Type 171 Mk 4.

For search and rescue duties the Type 171 Mk 4 has an hydraulic pump attached to the drive on the main gear-box and an hydraulic winch on the starboard side. Three deckchair seats are attached to the rear bulkhead and a specially shaped lightweight drip tray is laid on the floor. The starboard rear entry is closed by a canvas screen and the port entry by a side panel or blister.

In the aerial-crane rôle the machine carries a beam with a quick-release hook attached to strongpoints close to the centre of gravity. Electrical and manual quick-release cables are led to a position near the pilot.

For crop spraying a tank is fitted on each side of the machine and spray booms, steadied by wire stays, are attached. A spray pump is plugged in to the aircraft's electrical supply.

Leading data are: rotor diam., 48ft 7in; overall length (folded), 46ft 2in; basic weight (including VHF) in passenger role, 4,010 lb; gross weight, 5,400 lb; max. speed at s.l. (5 min rating), 126 m.p.h.; max. economical cruising speed at 2,000ft, 91 m.p.h.; max. vertical rate of climb (5 min power) 180ft/min; max. climb at forward speed (5 min power), 920ft/min at 60 m.p.h.; max. range with 65 gals of fuel, 268 miles.

FAIREY JET GYRODYNE • This machine is an experimental development of one of the two original Gyrodynes, dating from 1947/48. It has been rebuilt for experimental and development flying in connection with the massive Rotodyne (see page 294), and relatively minor alterations have allowed the installation of a new rotor head and a two-blade rotor, with pressure jets at the tips. The Leonides engine in the rear of the fuselage drives two pusher propellers mounted at the extremities of the stub wings, and also provides power for the compressor which produces air for the tip jets. There is a conventional tail with twin fins and rudders.

WESTLAND-SIKORSKY S-51 (DRAGONFLY) • The S-51 is a pioneer type of helicopter, and though out of production in its mother country, the U.S.A., is still being produced at the Westland works. For the British military variants the name Dragonfly has been adopted; these variants are: H.R.1, Leonides 50 engine, for air/sea rescue and photography with the Royal Navy; H.C.2, an R.A.F. variant with Leonides 24 engine, intended for casualty evacuation, with two stretcher cases or alternative

Westland-Sikorsky S-51. The drawings (reading down) are of the S-51, the S.E.3120 Alouette and the S.O.1310 Farfadet.

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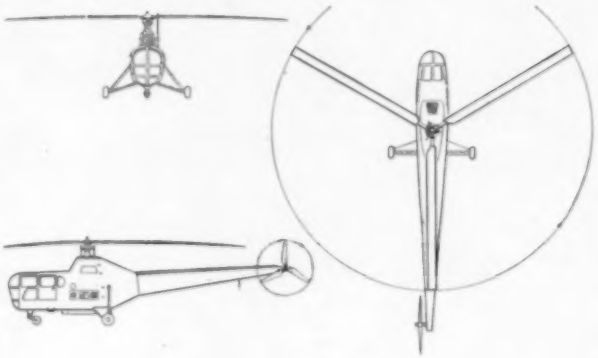
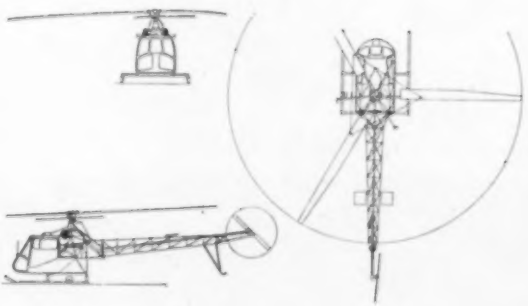
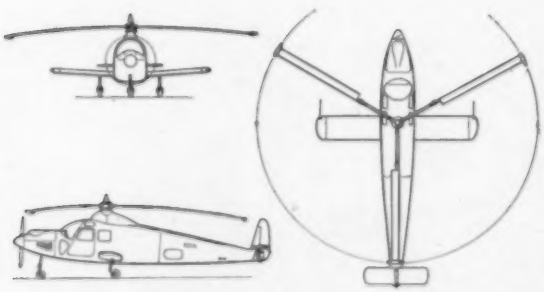
accommodation for seated casualties; H.R.3, Leonides 50 engine, all-metal main rotor blades with hydraulic servo control, for the Royal Navy; H.C.4, similar to H.R.3 but for R.A.F. service. The following description and performance data apply to the standard civil Type S-51.

The centre portion of the fuselage is of welded steel-tubes; it carries the main wheels and rotor-head structure and houses the engine and tanks, together with auxiliaries such as the electrical generator, radio and batteries. The standard power plant is an Alvis Leonides but, alternatively, a Pratt and Whitney Wasp Junior B can be installed. For ease of starting in cold climates a high-pressure priming system is fitted which injects 100 octane fuel from a separate small tank into the induction manifold.





S.E.3120 Alouette. (Below) S.O.1310 Farfadet.



It is claimed that the recently introduced all-metal main rotor blades offer new standards of durability and complete immunity to temperature and humidity effects, while the hydraulic servo controls greatly reduce pilot fatigue by eliminating control opposition and vibration. Equipment to special order includes special camera and radio installations, amphibious pontoon undercarriage gear, long-range overload fuel tanks and an hydraulic winch hoist. For ambulance work twin outboard panniers have proved most convenient; these are so constructed that the top half, which carries Perspex windows, can be removed, enabling the stretcher to be placed in position at a convenient height from the ground. The pilot or medical attendant can see the patient during flight.

Leading particulars are: main rotor diam., 49ft; length (rotors at extreme positions), 58ft 1½in; length (main rotor folded), 42ft 11in; height, 12ft 11¾in; empty weight, 4,300 lb; gross weight, 5,700 lb; max. speed (5 min rating), 104 m.p.h. at 202 rotor r.p.m.; max. weak mixture cruising speed, 86 m.p.h. at 189 r.p.m.; max. vertical rate of climb (take-off power), 280ft/min; max. range with 83 gal of fuel, 308 miles; max. endurance (83 gal), 5 hr; service ceiling, 13,000ft; hovering ceiling (without ground cushion), 600ft.

S.E.3120 ALOUETTE • Originally intended specifically for agricultural use, the Alouette is now being offered as a multi-purpose helicopter for civil or military service. In its design the following considerations were foremost: simplicity and ruggedness of construction, ease of maintenance, ready interchangeability, and easy handling. The c.g. limits are 7in forward to 0.4in aft of the rotor centre-line, and it is claimed that these limits allow single-seat or three-seat operation without any need for ballasting. The three-blade main rotor is driven by a 200 h.p. 9NH Salmson nine-cylinder radial engine through a gear-box located between the engine and the rotor itself; included in the gear-box assembly are the cooling fan, clutch, reduction gearing, free-wheel unit and drive for the anti-torque rotor. For simplicity and accessibility the rear fuselage is of open-lattice type and is readily detachable from the cabin. The standard undercarriage is of skid type. For crop-spraying or dusting, containers are mounted on the sides of the fuselage, and as an ambulance the machine carries the pilot and two stretchers.

Principal data are: rotor diam., 38ft; length, 34ft 3in; height, 9ft 6in; weight empty, 1,650 lb; gross weight, 2,750 lb; max. speed, 78 m.p.h.; speed for max. range, 62 m.p.h.; climbing speed (full throttle at s.l.), 500ft/min; ceiling in ground effect, 2,200ft; endurance (at max.-range speed), 2 hr 45 min (normal tankage); endurance with auxiliary fuel tanks, 6 hr.

S.O.1310 FARFADET • Of more than usual interest, the Farfadet is of the "gyrodyne" type; that is to say it is capable of landing and taking off vertically but has a relatively high maximum speed, by virtue of its tractor airscrew and fixed wing. It is not always realized that this machine has two wholly independent power plants: in the nose is a 360 h.p. Turboméca Artouste II turboprop, driving a two-blade controllable-pitch airscrew, and at the rear a 360 h.p. Turboméca Arrius II, which delivers compressed air to the nozzles at the rotor tips. The three-blade rotor is similar to that of the Ariel III, an experimental jet-driven helicopter of the same manufacture. All fuel is carried in the wings, the main portion of the fuselage being given over to the cabin, which has side-by-side dual controls and a third seat in the rear. Alternative to this rear seat two stretcher cases or freight can be accommodated.

The following are the only data released: rotor diam., 36.5ft; span of fixed wing, 19ft; cruising speed, 150 m.p.h.; range at 150 m.p.h., 250 miles.

RUSSIAN HELICOPTER (S-51 TYPE) • As our illustration shows, this helicopter, of unknown designation, but often ascribed to Mikhail Mil, displays features of the Sikorsky S-51 and Bristol Sycamore. Apparently a three-seater, it was first seen in public at the Tushino airfield, near Moscow, in July, 1951.

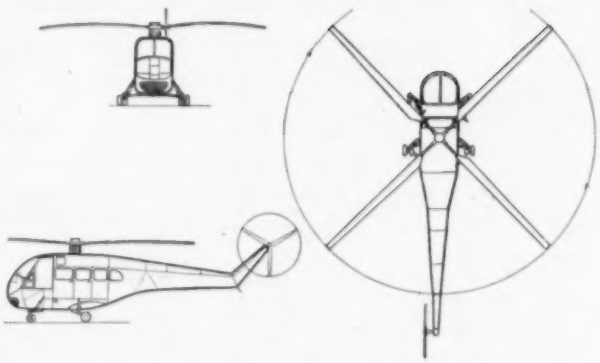
DOMAN LZ-5 (YH-31) • During October last year Doman Helicopters, Inc., announced that Hiller Helicopters, Inc., would produce their YH-31 evacuation-ambulance helicopter for the U.S. Army. "The decision to licence Hiller," it was stated on that occasion, "was made to minimize the time required for a larger military production."

The YH-31 is the "cas. evac." version of the basic civil LZ-5 multi-purpose design. A point of interest is that inclination of the tip-path plane of the four-blade rotor relative to the fuselage is accomplished by gimbal-mounting the rotor hub and rotating it with a constant-velocity driving system. Thus, no blade-flapping hinges, drag hinges or hinge dampers are required, and the bearings subject to centrifugal loads with oscillating motion are reduced to a minimum. The rotor retains dynamic balance in all flight attitudes, with consequent decrease in vibration, and the makers remark that though there are certain other rotor systems employing a gimbal mounting, these are subject to a condition of dynamic unbalance. The reduction gear is incorporated as an integral part of the rotor assembly. All moving parts are contained in a common housing which precludes contamination, and circulating oil is pumped to all bearing surfaces.

The Lycoming SO-580-D eight-cylinder horizontally opposed air-cooled engine of 400 h.p. is mounted low in the nose of the fuselage, with its crankshaft inclined upwards at an angle of 32 deg. There is a fluid drive with a mechanical pick-up on the engine crankshaft flange, coupled with a tubular drive shaft having universal joints. The tail rotor is driven from a gear in the main rotor assembly at an r.p.m. ratio of 2.09:1. Above the

Russian helicopter (S-51 type).

(Above and below) Doman LZ-5.

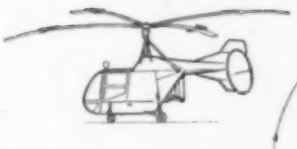


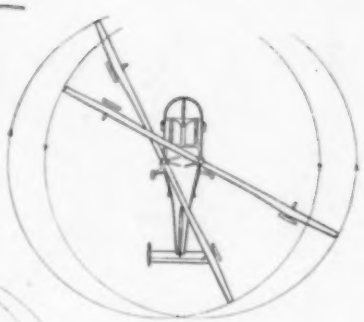
Gyrodyne GCA-2C.

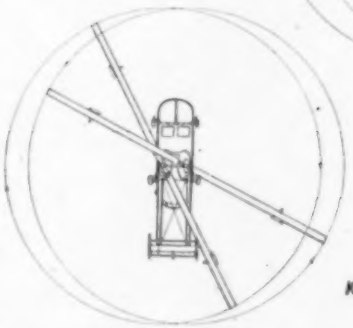
Kaman HOK-1.

Kaman HTK-1.

Kaman HTK-1.







Kaman HOK-1.

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power plant section, from which the engine can be rapidly removed without recourse to hoisting equipment, is the cabin, to the rear of which is stowage for baggage. The rotor blades are interchangeable and each has a spar built up of plastic-bonded birch laminations, with a plastic-bonded mahogany plywood covering.

On each side of the fuselage is a 7ft-wide folding door, which affords rapid loading of patients in safety and comfort—an important factor in helicopter rescue. When two stretcher patients are carried the retrieving radius is 240 miles, and the spacious cabin—of 147 cu ft capacity—allows an attendant to be carried.

A projected development will have two 200 h.p. Boeing Model 502 turboprops, which will permit a useful load of 2,140 lb to be carried at speeds up to 90 m.p.h.

Leading data for the YH-31 are: main rotor diam., 48ft; fuselage length, 38ft; disc area, 1,810 sq ft; disc loading, 2.44 lb/sq ft; empty weight, 2,860 lb; gross weight, 4,419 lb.

GYRODYNE GCA-2C • Powered with a Pratt and Whitney Wasp Junior engine of 450 h.p., this six-seat, two-blade, co-axial helicopter was being evaluated last year under a contract from the U.S. Navy. The rotors are of the semi-rigid type and incorporate automatic locks which prevent them from flapping at low rotor speeds and permit operation in high winds. There are only five gears in the transmission system.

Data are: rotor diam., 48ft; weight empty, 3,800 lb; gross weight, 5,400 lb; disc loading, 2.98 lb/sq ft; max. speed, 110 m.p.h.; hovering ceiling (without ground cushion) 5,900ft; vertical rate of climb, 625 ft/min.

KAMAN HTK-1 • This training and utility helicopter for the U.S. Navy and Marine Corps is a development of the commercial Type K-225, but has rotors of increased diameter and horizontal tail surfaces connected to the collective pitch control for greater stability. The engine, a Lycoming 0-435 of 235 h.p., drives twin two-blade intermeshing rotors mounted on splayed-out shafts. As an ambulance the HTK-1 carries a stretcher case and attendant or two "sitting" cases in the fuselage and two additional stretcher cases in external litters.

The rotor diameter is 40ft and the fuselage length 20ft 6in.

KAMAN HOK-1 • A four-seater liaison helicopter now in production for the U.S. Navy, the HOK-1 has twin two-blade intermeshing rotors as has the HTK-1, but differs in a number of important respects, notably in that it has twin tail booms. In the liaison role the HOK-1 will carry four people but it is convertible to an ambulance, when it will take two stretcher patients and one sitting patient or an orderly in addition to the pilot. The engine is a Continental R-975-40 of 500 h.p. and is mounted at the rear end of the fuselage at an angle of 35 deg. The gross weight is about 3,500 lb. As on other Kaman types, blade-pitch is controlled by servo-flaps.

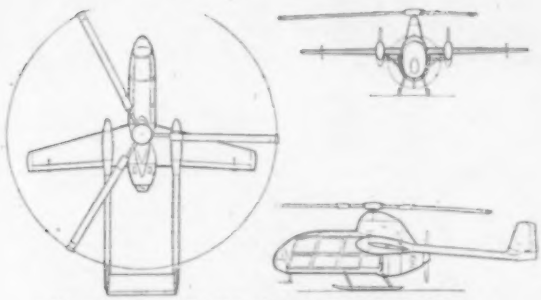
McDONNELL XV-1 • One of the most notable designs of the past year, the XV-1 is a high-wing monoplane with twin-boom tail, wings of 26ft span and a skid undercarriage. The engine is a Continental radial of 550 h.p., driving a McCauley pusher propeller and a blower which supplies air under pressure to rotor-tip jets. When the rotor is operating the propeller is braked and feathered, and when forward speed is desired a clutch disengages the engine from the blower and switches its power to the propeller. According to *Aviation Week*, fuel is fed to the tip jets through a rotor fuel governor driven from the rotor hub accessory drive.

The undercarriage skids are of aluminium and contain stainless steel straps on the "bungee" principle to absorb the shocks of unusually heavy landings.

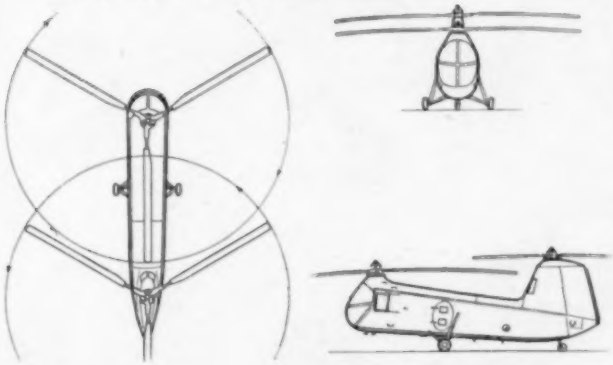
PIASECKI PD-18 RETRIEVER (HUP and H-25A) • Under the maker's designation PD-18, a family of U.S. Navy and U.S. Army helicopters has grown up. The symbols HUP signify U.S. Navy and H-25 denotes U.S. Army. The U.S. Army models are known by the name Army Mule.

The HUP-1, the first production model, has the Continental

McDonnell XV-1.



(Above) McDonnell XV-1. (Below) Piasecki HUP-2.



Piasecki HUP-2.

R-975-34 engine of 525 h.p., whereas the HUP-2 has the 550 h.p. Continental R-975-42 engine and an automatic pilot as the primary controller. This fitment has enabled the lateral tail stabilizers of the HUP-1 to be abandoned. The HUP-2 serves for anti-submarine, rescue and general utility duties. An improvement on this model is the HUP-3, and the H-25A is the U.S. Army version of this last-named machine, developed primarily as a close-support transport and likewise having the R-975-42 engine.

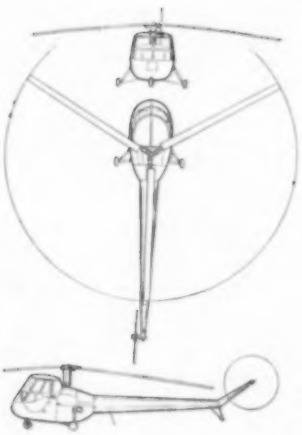
The following description relates specifically to the H-25A but in general is valid for the other models. Of typical Piasecki lay-out in having tandem rotors driven by a single engine, it is a six-seater, with a fuselage of all-metal, stressed-skin construction. Dual hydraulic controls are fitted, and there is a large rescue hatch (48in long × 26in wide) at the forward end of the cabin in the right-hand side of the floor, near the pilot's seat. An hydraulic hoist permits personnel, stretchers, etc., up to 400 lb in weight to be lifted through the hatch. The engine is fan-cooled and readily removable as a power package, including accessories and lubricating system.

Data are: rotor diam., 35ft; fuselage length, 32ft; weight empty, 3,928 lb; normal gross weight, 5,750 lb; overload gross weight, 6,100 lb; max. speed at s.l. (rated power), over 103 m.p.h.; cruising speed, over 80 m.p.h.; service ceiling, over 10,000ft; vertical rate of climb (take-off power), 650 ft/min; max. range, about 340 nautical miles; fuel capacity, 125 gal.

SIKORSKY S-57 • A convertiplane being built to U.S.A.F./U.S. Army specifications, and possibly designated XV-2, this is believed to have a two-blade rotor which can be braked and retracted into the main fuselage during forward flight. Gas turbine power is almost a certainty.

SIKORSKY S-52-2 • This fast 3/4-seat helicopter, little known outside America, was described in our previous review, but it can now be recorded that a machine of the type has flown under the power of a Turboméca Artouste II shaft-drive gas turbine. This French-built power unit is mounted at the top of the fuselage directly beneath the rotor head.

(Above and drawing)
Saunders-Roe Skeeter.



Canamerican S.G.VI.

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WEIGHTS BELOW 2,500 lb

SAUNDERS-ROE SKEETER • The Skeeter is Britain's smallest helicopter and is under development for both civil and military use. The first—Jameson-engined—prototype flew late in 1948, and about a year later came the Mk 2, with the D.H. Gipsy Major engine. The Mks 3 and 4, respectively, were for Army and Navy use, and though originally powered with Gipsy Majors, have since been re-engined with the Cirrus Bombardier. At the Society of British Aircraft Constructors' Display last year appeared the Mk 5, a civil variant, again with the Cirrus Bombardier. The following description applies in the main to the Mks 3, 4 and 5.

The main rotor has three constant-chord twisted blades, with provision for folding parallel to the rear fuselage. The hub and root portions are the only parts of the machine which cannot be reached from ground level. On the starboard end of the engine (for it is mounted athwartships) is a primary gear-box incorporating rotor-engaging and free-wheel clutches and connected by a short intermediate shaft to a secondary gear-box carrying the main rotor shaft. The tail rotor is driven from the secondary gear-box through shafting and bevel-gear boxes. The cyclic pitch stick and rudder pedals are duplicated and the other controls are grouped centrally.

The centre fuselage is basically a tubular steel framework enclosing the engine and supporting the main rotor shaft. Attached to it are the front and rear sections, both of conventional sheet-metal construction. The crew of two sit side by side and the observer's seat—to starboard—can be reversed if desired. In its place a 10-gal auxiliary tank may be fitted. The nosewheel undercarriage with which the prototypes have been flying is simple and remarkably light, but it is expected that for certain operations a skid undercarriage may be preferred.

Removal of cowlings completely exposes the engine, and the engine auxiliaries can readily be serviced from the port side. The clutch, cooling fan and primary gear-box can be taken off the starboard side without removing the engine, and the whole of the main rotor drive system can also be withdrawn—again without displacing the engine.

Leading particulars are: main rotor diam., 32ft; length (blades folded), 28ft 5in; height, 10ft 2in; gross weight, 2,100 lb; top speed at s.l., 115 m.p.h.; max. rate of climb at s.l., 1,250 ft/min at 50 m.p.h.; operational ceiling (200ft/min rate of climb), 13,000ft; absolute ceiling, 15,500 ft; hovering ceiling, 3,300ft; endurance at 86 m.p.h., 3 hr; endurance at 86 m.p.h. (with auxiliary tank), 4.5 hr.

CANAMERICAN S.G. VI • A Canadian design by Bernard Sznycer and Selma Gottlieb, the S.G. VI is expected to go into production in the country of its origin. It is powered with a Franklin 6A4-200-C6 engine of 200 h.p. driving a four-blade rotor with a diameter of 35ft. The empty weight is 1,750 lb, the normal gross weight 2,380 lb, and accommodation is provided for two passengers in addition to the pilot. Sea level rate of climb is quoted at 760ft/min, the max. speed 88 m.p.h. and cruising speed 78 m.p.h.

MATRA-CANTINIEAU MC.101 • Designed and first flown in France, the MC.101 is now under development in Madrid. As the photograph shows, the layout is unusual, the pilot being seated beneath the power plant and fuselage proper. The production version would have an enclosed cockpit, with side-by-side seating and dual controls, and the dural-tube skid undercarriage depicted in the drawing would be standard. The Hirth engine is driven from the gear-box and clutch through a Paulstra universal joint. Each of the three blades of the main rotor has a duralumin spar and roots of deep section;

the blades are not twisted. The tail rotor is driven by cardan shaft.

Advantages claimed for the MC.101 are absence of vibration; unusually low empty weight, due to the simplification of construction in the moving parts, blades and drive; low engine power (two persons on 105 h.p.); low cost price; and cheap operation.

Data are: main rotor diam. 26ft 3in; fuselage length, 21ft 9in; height overall, 7ft 6in; undercarriage track, 5ft 11in; weight empty, 880 lb; weight loaded, 1,320 lb; cruising speed, 62 m.p.h.; endurance, 2 hr.

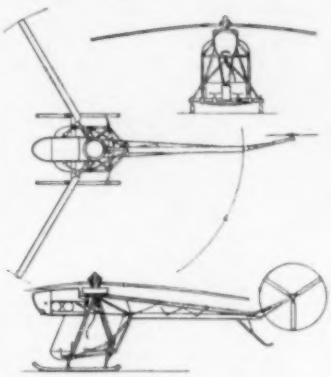
S.O.1220 DJINN • This remarkable little helicopter is propelled solely by compressed-air jets at the blade tips, and is claimed to be capable of carrying a useful load equal to its own weight. Its makers claim that if produced in quantity its cost price would not exceed five to six million francs—half that of light helicopters at present in use.

The Djinn was originally designed for the purpose of testing the new compressed-air jet formula, with only pipes and joints between the compressor and the jets, there being no intermediary heating, heat exchangers or combustion chambers. The makers point out that, though the thermodynamic efficiency of this arrangement is lower than that of other, more complicated, solutions, if a light compressor is used (such as the Turboméca Palouste actually specified), and if the rotor is carefully adapted, the result approaches the efficiency of devices which are theoretically more perfect, though more complicated.

The fuselage of the Djinn is a steel-tube structure, with the cockpit, having single or dual control, forward. The undercarriage is of skid type. The Palouste power plant is installed behind the cockpit, with the structure carrying the two-blade rotor between. Autorotation qualities are claimed to be equivalent to those of mechanically driven helicopters.

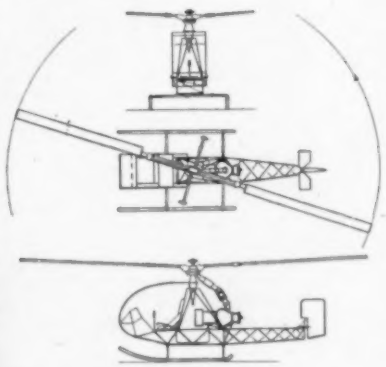
In military service the Djinn could be used for observation, reconnaissance and liaison, as an ambulance (with one or two

(Left) American Helicopter XH-26 Jet Jeep.



(Below, and drawing on right) Matra-Cantinieau MC.101.

(Drawing at lower right and lower picture) S.E.1220 Djinn.



Helicopters 1954 . . .

stretcher cases), or for ground attacks with infantry weapons. In civil operation it could serve for agricultural spraying, police work, power line inspection, forest patrol, and newsreel photography. As a trainer the type has obvious advantages.

Performance figures quoted hereafter take into account the increase in power of the Palouste, now under development. Data: rotor diam., 32.8ft; normal gross weight, 1,390 lb; max. weight with vertical take-off at s.l., 1,580 lb; max. speed, 81 m.p.h.; cruising speed for range, 62 m.p.h.; cruising speed for endurance, 37 m.p.h.; fuel consumption at cruising speed (gasolene or kerosine) for max. range, 220 lb/hr, for max. endurance, 185 lb/hr; service ceiling, 10,000ft.

LUALDI/TASSOTTI • A small helicopter powered by an 80 h.p. Continental engine and designed to cruise at about 75 m.p.h. has been designed by the Italians Carlo Lualdi and Sergio Tassotti, and is being built in the Lualdi works near Udine. The main rotor diameter is about 24ft, the fuselage some 20ft long, and endurance should be approximately 2½ hr.

AMERICAN HELICOPTER XH-26 JET JEEP • This experimental single-seater is powered with pulse-jets and weighs only 300 lb empty, although the designed gross weight is 900 lb. The pulse-jets are of the same manufacture and are located on the tips of the two-blade main rotor. Each has only one moving part, which, when worn, can be replaced in a matter of a few minutes. Fuel can be gasoline, kerosine or diesel oil. Though standing 6ft high, the machine can be collapsed into a 5ft × 5ft × 14ft container and can be dropped by parachute. Having been unpacked, it can be in the air within 20 minutes on its missions of observation or reconnaissance. The three-wheel undercarriage shown in the photograph is interchangeable with a twin skid gear. Top speed is about 80 m.p.h. and endurance 1½ hr.

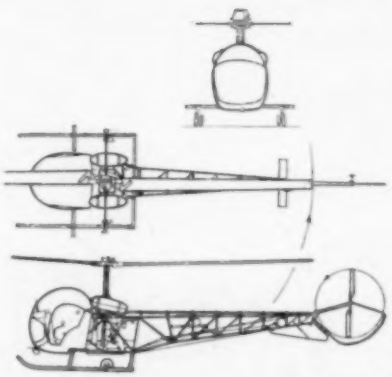
BELL MODEL 47G • This world-famous helicopter is used commercially, and in the service of many air forces, in numerous variations; thus, in the U.S.A.F. it appears as the H-13B, D, E and G, and in the U.S. Navy as the HTL-1, 2, 3, 4, 5 and 6. In Italy the Model 47D-1 is built under licence by Giovanni Agusta and is known as the Agusta-Bell. Subject of our description is the latest civil model, the 47G.

The two-blade main rotor has laminated wooden blades and a steel stabilizer bar. A new feature is a synchronizing elevator, which is linked directly into the control system and provides greater stability with a greatly increased c.g. travel. The engine is a six-cylinder Franklin 6V4-200C32 of 200 h.p., which supplies power to the main rotor, tail rotor, generator and cooling fan through a two-stage planetary transmission. Although the three-abreast cockpit has a bubble-type Plexiglass canopy, the remainder of the fuselage is left as open lattice work. The twin landing skids are of aluminium alloy, and ground-handling wheels and mooring and towing attachments are standard. An alternative fitment is a quick-change flotation gear in the form of twin pontoons, which convert the Model 47G into a very effective machine for all types of amphibious operation—especially from marsh and swampland.

Of the improvements incorporated in the 47G we have already mentioned the synchronized elevator; additionally, there are twin gravity-feed fuel tanks, which give 38 per cent more range, and an improved electrical system. Kits can be supplied to equip

Bensen Mid-Jet.

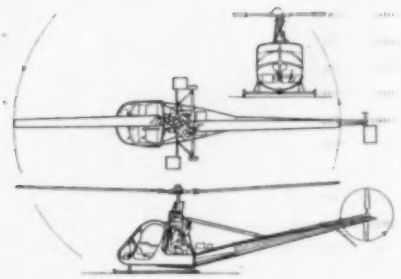
Brantly B-2.



(Photograph below and drawing right) Bell Model 47G.

(Photograph, right, and drawing below it) Hiller Model 12B.

(Below) Hiller Hornet.



out, the B-2 has a single main rotor and tail rotor, and, as the photograph shows, the fuselage is of notably clean design. The makers state that flight tests have proved "most satisfactory," and that they are in the process of installing dual controls and two-way radio. The makers, the Penn Elastic Company, Inc., report that all tests should be completed by August.

Data are: rotor diam., 23ft; fuselage length, 17ft 11in; height, 6ft 10in; fuel capacity, 16½ gal; weight empty, 740 lb; gross weight, 1,250 lb.

the machine with rescue litters, two types of external cargo carriers, VHF multi-channel radio, or spraying, dusting or fogging equipment.

Leading data are: rotor diam., 35ft 1½in; overall length, 41ft 2½in; empty weight, 1,380 lb; gross weight, 2,350 lb; max. permissible speed, 90 m.p.h.; cruising speed, 77 m.p.h.; max. rate of climb at s.l., 800 ft/min; climb to 5,000ft, 8 min; ceiling, 12,500ft; service ceiling, 10,900ft; hovering ceiling in ground effect, 3,600ft; range, 215 miles; endurance, 3.8 hr.

BENSEN MID-JET • Primarily intended for military use, this is a single-seat helicopter weighing only 100 lb empty, powered by two ramjet units, each weighing only 5 lb, on the tips of the rotor blades, and claimed to be capable of lifting more than four times its own weight. Construction is complete but the makers "await a Government contract for further work." Speeds of "up to 80 m.p.h." are mentioned by the makers. Rotor diameter is 15ft.

BENSEN SKY SCOOTER • A projected two-seater now undergoing flight tests, this little machine is designed for two "special engines" built by the Bensen organization.

BRANTLY B-2 • The prototype of this two-seater is powered by a 150 h.p. Lycoming engine but a Continental of similar output is an alternative installation. Conventional in lay-

(Below) Hoppi-Copter.

McCulloch MC-4C.

Helicopters 1954 . . .

CESSNA PROJECT • The helicopter division of the Cessna Aircraft Company, which took over the Seibel designs described in our former review, is now developing a new, all-metal, 2/4-seater helicopter, but details are unlikely to be available until the middle part of this year.

HILLER HJ-1 HORNET (H-32 AND HOE) • The Hiller Hornet HJ-1, as now in small-scale production for the U.S. Navy, the Marines and the Army, bears little resemblance to the first Hornet, which was constructed solely to demonstrate the practicability of ramjet-propelled rotor blades. Under the Navy designation HOE and the Army designation H-32, the type is intended primarily as a trainer. Power is provided by two Hiller 8RJRBC ramjets, each developing about 30 lb net thrust and weighing 11 lb, mounted on the tips of the two-blade rotor. There are no moving parts whatsoever in the ramjets and they may be changed in a matter of minutes with no other tool than a screwdriver. Before these units can be started the rotor must be spun at 150 r.p.m. by some extraneous means, i.e., a 1 h.p. petrol engine, which is itself started by a cord. Once the main rotor is revolving the main fuel-flow valves are opened and the starter button pressed, thereby activating a magneto and energizing electrodes in the ramjets.

The cyclic-pitch control column is of the hanging type, branched for use by either occupant, and the collective-pitch levers incorporate the fuel-flow valve.

With an empty weight of little more than 500 lb, the HJ-1 can lift more than its own weight. The rotor diameter is 23ft and the height 8ft.

HILLER MODEL 12B (H-23B AND HTE-2) • The Hiller 12B is a commercial helicopter built to sell for $36,000. The U.S. Army's H-23B is generally similar but is arranged for training and casualty evacuation; additionally it is used to familiarize Army personnel with helicopter operations and tactical employment, and mapping in Alaska has also been undertaken with this model. The U.S. Navy's HTE-2 is the standard helicopter trainer in the Naval Reserve helicopter programme of that Service, and is also employed for liaison, recruiting, photography and on miscellaneous public relations activities. Twenty HTE-2s have been supplied to the Royal Navy. The following description applies essentially to all models.

The two-blade main rotor is provided with the Hiller "paddle control" system of servo rotors, which tilt the rotor head to effect cyclic pitch change. The blades of the main rotor have a steel spar along the leading edge and are built of solid wood laminations covered with Fibreglass and having stainless steel along the nose portion. The cabin enclosure is supported by a semi-monocoque platform structure with the seats, controls, engine mounting and undercarriage. A characteristic feature is the corrugated-metal boom which stems from the bottom of the main structure and carries the tail rotor.

The engine, a Franklin Model 6V4-200-C33, is fan-cooled and is mounted with the main shaft vertical. The cockpit has three side-by-side seats with dual controls, and the cyclic pitch levers and collective pitch levers are to the left of the seats. In the casualty evacuation role the H-23B carries two folding stretchers, one on each side of the cabin. The 12B and H-23B have a wide-track, skid-type undercarriage, whereas the HTE-2 has a four-wheel gear with Hiller shock-absorber struts.

Leading particulars are: rotor diam., 35ft; length, 38.7ft; height, 9.8ft; max. fuselage width, 5ft; disc loading, 2.6 lb/sq ft; empty weight (12B), 1,656 lb; gross weight, 2,500 lb; fuel capacity, 28 gal; cruising speed at s.l., 70 m.p.h.; top speed at s.l., 84 m.p.h.; rate of climb at s.l., 770 ft/min; hovering ceiling in ground effect, 3,200ft; service ceiling, 9,400ft; range, 135 miles.

HOPPI-COPTERS • It is stated by Hoppi-Copters, Inc., that they are working on a new model of their tiny single-seat helicopter, though they consider it too early yet to furnish pictures or data. Illustrated is one of the later models of the preceding series, powered by a single 45 h.p. engine. It has co-axial rotors of 18ft diameter, and weighs 450 lb all-up. The designed maximum and cruising speeds are 60 m.p.h. and 45 m.p.h. respectively, and the maximum range 150 miles.

McCULLOCH MC-4C • An Approved Type Certificate for this twin-rotor helicopter was issued early last year, and the prototype underwent tests with the U.S. Army under the designation YH-30. The machine has two tandem seats and is powered with a 200 h.p. Franklin 6A4-2006-C6, which drives a horizontal shaft through the upper fuselage, the rotors in turn being driven through right-angle reduction-gear units of 4.44 : 1 ratio. A vee-belt central drive links the engine to the main shaft.

Data are: rotor diam., 23ft; length, 32ft 5in; weight empty, 1,600 lb; gross weight, 2,300 lb; max. speed, 105 m.p.h.; cruising speed. 85 m.p.h.; max. rate of climb, 1,000 ft/min; service ceiling, 10,000ft; range at 75 m.p.h., 200 miles.

McCULLOCH SINGLE-SEATER • The U.S.A.F. is reported to be showing interest in a 45 h.p. single-seat McCulloch helicopter having an empty weight of 210 lb and a gross weight of 500 lb.

HELICOPTER CONSTRUCTORS

Great Britain: Bristol Aeroplane Co., Ltd., Filton, Bristol; Fairey Aviation Co., Ltd., Hayes, Mddx.; Percival Aircraft, Ltd., Luton Airport, Beds; Saunders-Roe, Ltd., Osborne, East Cowes, Isle of Wight; Westland Aircraft, Ltd., Yeovil, Somerset. *France:* Société Nationale de Constructions Aéronautiques du Sud-Est, 6 Avenue Marceau, Paris (VIIIe); Société National de Construction Aéronautiques du Sud-Ouest, 105 Avenue Raymond-Poincaré, Paris (XVIe). *Italy:* Giovanni Agusta, Cascina Costa, Gallarate (Varese), Italy. *U.S.A.:* American Helicopter Co., Inc., 3613 Aviation Boulevard, Manhattan Beach, California; Bell Aircraft Corporation, P.O. Box 1, Buffalo 5, N.Y.; Bensen Aircraft Corporation, P.O. Box 2621, Raleigh, N.C.; Canamerican Helicopter Manufacturing Co., Ltd., Brooklyn, New York; Cessna Aircraft Company, Wichita, Kansas; Doman Helicopters, Inc., Municipal Airport, Danbury, Connecticut; Gyrodyne Company of America, Inc., St. James, Long Island, N.Y.; Hiller Helicopters, Inc., 1350 Willow Road, Palo Alto, California; Hoppi-Copters, Inc., 713 1411, 4th Avenue Building, Seattle 1, Washington; Hughes Aircraft Company, Florence Avenue at Teale Street, Culver City, Cal.; Kaman Aircraft Corporation, Bradley Field, Windsor Locks, Connecticut; Kellett Aircraft Corporation, Central Airport, Camden 11, New Jersey; McCulloch Motors Corporation, Aircraft Division, 9775 Airport Boulevard, Los Angeles 45, Cal.; McDonnell Aircraft Corporation, St. Louis 2, Missouri; Penn Elastic Company, Inc., 20 Maplewood Avenue, Philadelphia, 44; Piasecki Helicopter Corporation, Morton, Pennsylvania; Sikorsky Aircraft Division of United Aircraft Corporation, South Avenue, Bridgeport, Connecticut.

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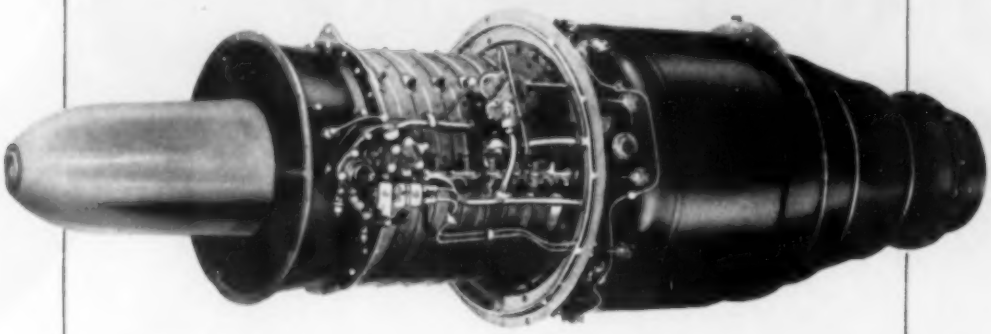

Variations . . . long life or short life

The Viper turbojet is now being developed in two forms, 'short life' for the Australian Jindivik pilotless target aircraft, and 'long life' for the Percival Jet-Provost Trainer for the Royal Air Force. The 'short life' version — the Viper ASV3 — has been type tested and is in production at 1,640 lb. thrust. Development to higher performance is proceeding. The 'long life' engine for training aircraft — the Viper ASV5 — also develops 1,640 lb. thrust, and this highly efficient and simple power unit will have a very long overhaul life. A licence agreement with Avions Marcel Dassault of Paris for the manufacture and development of the Viper is now in operation.

ARMSTRONG SIDDELEY *Viper* TURBOJET

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Public esteem of the helicopter as a transport vehicle was greatly strengthened last summer when H.R.H. the Duke of Edinburgh made time-saving journeys in a Sikorsky S-55 of No. 705 Squadron, Fleet Air Arm. This telephoto shot depicts the helicopter in the grounds of Buckingham Palace, with H.M. the Queen and the Duke standing near the tail.

HELICOPTERS AT WORK

An Outline of their Contributions to Civil Aviation

THE helicopter has saved thousands of lives, but taken few; it has constructed much, but destroyed little. This encouraging theme has dominated the early, evolutionary years of the "universal vehicle." Igor Sikorsky, the "dean" of helicopter development, has said that the life-saving work of rotorcraft in Korea alone would amply justify the total effort and expense involved in the creation of the helicopter—even if it never performed another useful service to mankind.

But we can be certain that its useful life is just beginning. This brief survey scans the part played by helicopters in modern transport. There is no foreseeable limit to the tasks for which it is suited or will become available in the near future.

In Korea approximately 25,000 wounded United Nations soldiers and Korean civilians were evacuated from the battlefront by helicopter. There is no way of telling exactly how many lives were saved in this way, but it has been stated that nearly 98 per cent of the American soldiers wounded in Korea survived and that 85 per cent were able to return to duty. In Malaya, hundreds of British soldiers wounded in fighting the terrorists have been evacuated by helicopter, and thousands of troops "lifted" into the jungle battleground; a Naval pilot describes these operations in an article in this issue.

During the disastrous flooding of the Netherlands last winter, rotorplanes saved more victims than all other methods of transport combined: some 2,000 people were rescued by a joint operation involving 38 helicopters from six different countries. The value of the helicopter in an emergency was demonstrated once again during the Austrian avalanches last January.

Except in America, where helicopters have long been in daily use with coastguard, police and port authorities, no energetic efforts have been made to form civilian helicopter services, even on a small scale, for routine and emergency work. Sole responsibility for supplying helicopters and crews at a time of need should not be left permanently in military hands, although in Europe—no doubt largely for financial reasons—this has been permitted to date. In Britain, Service authorities were initially slow to make use of the helicopter. As a result, potential civil users were deterred by the low availability and high cost of equipment—hence the fact that there is still only a handful of rotorplanes on the British Civil Register. And America maintains her long-established leadership in helicopter production.

Emergency applications of rotorcraft, as in Holland, have received separate mention because there is no way of evaluating services which result in the saving of even one human life. As a general rule, scheduled commercial services with helicopters may be regarded as uneconomic, due to the high operating cost of the small machines available so far. Exceptions occur where operators

(Left) Early this year Swiss and American helicopters helped to rescue victims of the Austrian avalanches. This Swiss Hiller, with an external stretcher, is seen at work in the village of Blons. (Right) Two of the 38 rotorplanes used during the Dutch floods—a B.E.A. Sikorsky S-51 and an American Bell H-13—are pictured on a road in the island of Goeree-Overflakkee.

An early demonstration of the helicopter's humanitarian role was the supply mission flown to the Wolf Rock Lighthouse in February 1948 by the Westland Aircraft Company's S-51 demonstrator. Pilot Alan Bristow was subsequently awarded a R.Ae.C. Silver Medal.

HELICOPTERS AT WORK . . .

have taken advantage of the indirect subsidy available from airmail, which can demand a relatively high return per ton-mile in return for a speedy and efficient service over short routes. Incidentally, a spokesman of Los Angeles Airways has claimed that on a cost per ton-mile basis his company's mail pay is only about 25 per cent of that received by the best fixed-wing local airlines.

L.A.A.'s helicopter mail services in the Los Angeles area began in October 1947 and its aircraft have since flown aver 30,000 hours. A close second is Helicopter Air Service, which began operations in the Chicago district in August 1949 and has since carried about 7,000 tons of mail without accident. The company now holds a passenger licence.

After operating a scheduled freight service in the New York area for nine months, New York Airways opened, in July last, a passenger service connecting the three major New York airports. National Airlines recently became the first of America's established fixed-wing carriers to enter the helicopter field: this company has one S-55 and proposes to operate two more on an inter-city network in Florida.

Existing and proposed helicopter services fall into two categories —metropolitan and inter-city. Pending the advent of large helicopters, most American operators are thinking in terms of metropolitan services, which would carry passengers on the same basis as mail and freight, *i.e.*, at the highest rate which the traffic will bear. This philosophy is summed up in another quotation from the Los Angeles Airways spokesman: "If the helicopter can save the passenger an hour or two over the taxi it should get the same fare as the taxi; *viz*, 25-30 cents a mile. On longer trips, of course, the cost should drop, but 10 cents a mile would be the absolute minimum."

In Europe, opportunities for metropolitan service are fewer. The Post Office, for example, have been unable to continue their encouragement of B.E.A., who are also virtually prohibited from operating their present equipment into the heart of London by the lack of a suitable heliport and the performance regulations affecting single-engined helicopters. Although the Corporation's helicopter unit was founded as long ago as 1947, its operational experience has consisted mainly of mail and passenger services operated in each case for a very limited period only. In contrast with the plans of the U.S. metropolitan operators, B.E.A. envisage helicopters which will compete with fixed-wing, land and sea services on distances of up to 200 miles. The advent of a suitable British helicopter for this purpose, large enough and ready for passenger service, remains at least five years distant.

Belgium's national airline, Sabena, opened a 270-mile inter-city mail circuit with Bell 47s in 1950. The tonnage carried on this route now approaches 200. In June last year the airline began to take delivery of its three S-55s and the first stage in a logical progression from mail to passengers began in August with the inauguration of an experimental freight service. By September 1st, Sabena were ready to open the world's first international passenger route flown by rotary-wing aircraft. The S-55 network now flown takes in eight cities in five countries, and the large Sikorskys have also taken over the mail circuit from the Bells, which have been sold. Since "fixed-wing" fares are charged, Sabena's inter-city S-55 network is evidently uneconomic as such; but this apparent disadvantage is easily offset by (a) the experience gained; (b) the fact that a good proportion of the helicopter passengers are fed into long-haul services operated from Brussels; and (c) the prestige value of being the world's first operator of international helicopter services.

The total flight time built up with all types of rotary-wing aircraft is estimated to be in the region of three million hours; helicopters produced by the Bell company alone have logged over one million. One of the most intensely utilized Bell 47s, the first of six delivered to Helicopter Air Services of Chicago, recently passed the 4,000 hr mark. Although it still has the original set of rotor blades, this machine has outlived eleven transmission systems. Component-renewal on such a scale is, of course, an expensive business and, coupled with high fuel and maintenance costs and small payloads, accounts for the present small scale of airline operations with rotorcraft.

This study of a New York Airways S-55 "Skybus" over the temporary terminal area at Idlewild illustrates well the "metropolitan" role of the helicopter: i.e., as a connecting link between neighbouring airports and between city-centres and airports. National Air Lines, owner of the DC-6 on the left, recently became the first large American fixed-wing carrier to operate helicopters.

Outside the realm of scheduled transport, however, most applications of the helicopter are essentially economic: high operating costs become of secondary importance when the helicopter is shown to be capable of tasks which would be impossible to perform, or would take years to complete, with any other equipment.

The founder of Okanagan Helicopters of Vancouver, Mr. Carl Agar, has done more than most people to demonstrate the unique powers of the helicopter. We quote some examples of the tasks successfully performed with Okanagan's fleet of three S-55s and five Bell 47s in turbulent mountain districts at altitudes of up to 10,000ft: transporting on to a mountain platform pre-fabricated components for a complete village of 25 houses; moving 13 tons of freight, consisting of mining equipment, food, living accommodation for seven men and a cookhouse, from a floating platform on a river to a mountain ridge 18 miles away and 3,000ft high; a 200-ton lift of all structural material required to dam the Palisade Lake, plus a concrete mixer and a rowing boat.

Undoubtedly the largest engineering project which has yet involved the use of helicopters is the Aluminium Company of Canada's plan, now well advanced, for damming a chain of lakes and transferring water by tunnel through the mountains to a

massive hydro-electric station. Connection between the power house and the company's smelting site at Kitimat, 50 miles away, is by power lines which cross mountain ranges of up to 5,000ft high. One of the main problems facing the engineers entrusted with this $500 m project was that of finding the best route for the power lines, a task which might have taken a ground survey party up to three years. In 1949, with the aid of Mr. Agar's Bell 47, the answer was found in less than 30 hours' flying time. Today a fleet of 10 helicopters is employed regularly on the "Alcan" scheme—for transport of personnel, supplies and equipment (often landing on platforms only 14ft square), survey and cable laying. In 1951 Mr. Agar's efforts were recognized by the award of the McKee Trophy for the previous year's "greatest contribution to the advancement of aviation in Canada."

There are hundreds of examples of the almost incredible amount of time which can be saved by using rotorplanes on survey and construction work in difficult terrain. The Pennsylvania Electric Company found that the helicopter would patrol power lines at the rate of 28 m.p.h. compared with a previous maximum of 10 miles *per day* on foot. Another company reports that helicopter power line patrol is 60 per cent cheaper than the normal surface method. Ten Bell 47Ds of Rick Helicopters Inc., probably the world's largest civil operator of rotorcraft, completed in three and a half months an Alaskan survey for the U.S. Army map

Ship-borne helicopters are being used in many parts of the world, by navies and for civil purposes such as whaling, fishing and survey. In the last-named category we illustrate the Bell 47 carried on the Canadian ice-breaker "d'Iberville," which has a hangar and flight deck for her two rotary-winged scouts.

Crop-spraying is illustrated (left) by a Hiller 360 of Pest Control, Ltd., in action against potato blight at Stalham, Norfolk. The Bell 47 below, dusting foliage in a typical North American setting, provides contrast in method and locality.

On Coronation Day, films for distribution abroad were rushed to London Airport by Bristol Sycamore One of these military versions of the Type 171, a Sycamore H.R.13, is pictured setting off on a rehearsal journey from the T.V. station at Alexandra Palace.

HELICOPTERS AT WORK . . .

service which, it is claimed, would have taken 20 years to accomplish by any other method. In western Canada Associated Helicopters of Edmonton, Alberta, completed in six weeks a geological survey which would otherwise have occupied three seasons, or 72 weeks, using the traditional pack-horse-and-canoe method. Australia, too, is planning prospecting operations by helicopter.

The extent to which aviation has become an integral part of modern agriculture is not generally appreciated in this country. On this subject, America can produce some astounding statistics. In 1951, for example, aircraft used for dusting, spraying, fertilization, seeding, defoliation, pest-abating and like activities flew 685,000 hours, spread 138,000 tons of chemicals over an area larger than the State of West Virginia and sprayed nearly 36 m gallons of insecticides. The number of aircraft used by farmers and ranchers of both professional and private purposes is rather more than 12,000.

Among agricultural aircraft, helicopters are still in the minority, but recognition of their value increases daily. Once again, their ability to hover, to fly extremely slowly, and to operate from minute areas often compensates for the higher capital outlay and operating cost. The helicopter used to round up cattle at the Wagoner Ranch in Texas, one of the largest in the world, is said to do the work of 15 cowboys. Specialist operators are responsible for most of the dusting and spraying work done by rotorcraft but it seems reasonable to foresee a time when—on larger farms and ranches at least—the rotorcraft will be accepted as a straightforward piece of farm equipment.

In the sphere of agricultural helicopter operations, Britain is well represented by Pest Control, Ltd., which began work in 1948. This company has built up over 6,500 hours of rotorplane experience on an impressive variety of contracts. Problems of tropical operation have been overcome during the course of several seasons' work on cotton plants in the Sudan. Colorado beetles in Normandy, cockchafers in Switzerland and bollworms in South Africa are among the creatures which have received sentence.

During a recent Helicopter Association lecture, Mr. J. E. Harper of Pest Control described thus an interesting night-flying experiment undertaken in the Sudan: "The helicopter was fitted with headlights, tested, and we continued our treatment of cotton for five or six nights. The spraying results were effective, and I found it possible to fly a machine at 40 m.p.h. as low as 6ft over the top of the cotton. However, the lighting called for much more development work as severe dazzling occurred along the fuselage when crossing canal banks and fallow ground, and when landing and taking off. This was accelerated by the dust stirred up by the downwash. In my opinion, given sufficient pilots to avoid fatigue over suitable areas and with further development of lighting and technique, air spraying by night is feasible with helicopters, another unique feature of this type of aircraft."

While enthusiastic about helicopters this company is fully aware of their present limitations, and in 1950 supplemented its four Hillers with a fleet of six Austers. Mr. Harper believes that the helicopter economics, as far as aerial spraying are concerned, would be greatly improved by the production of a simple 250-300 h.p. rotorplane capable of hovering at 5,000ft with a payload of at least 900 lb, a cruising speed of 100 m.p.h., an endurance of 2½ hours and costing no more than £5,000. He suggests that the tip-jet helicopter may become ready for agricultural service before it is suitable for passenger or freight work.

More than 85 per cent of Pest Control's spraying work is performed a few feet above the ground, which, coupled with the continuous manœuvring and frequent take-offs and landings makes the pilot's work very arduous. "An average of four hours flying per day is sufficient," Mr. Harper notes, although "some of our pilots have exceeded eight hours on some days." Utilization of the helicopter varies greatly under different operating conditions, as indicated by the fact that Pest Control's Hillers have covered a maximum area of 550 acres per day in the United Kingdom and of 1,260 acres daily overseas.

Maritime use of rotorcraft dates from as long ago as October 1931, when a U.S. Navy pilot performed autogyro trials from the carrier *Langley*. Helicopters are now widely used by several navies for rescue work, reconnaissance and for inter-ship and ship-to-shore liaison. The hazards of deck flying have been reduced a good deal by the constant attendance of the rotorplane with its winch and rescue-harness. This is also an economical method of rescue because one helicopter can—by day at least—do the work of a destroyer. A logical extension of this method could be the use of large helicopters to supplement the service traditionally provided by lifeboats.

Two important experiments in the use of shipborne helicopters took place in 1951; trials with a S-51 were successfully carried out on the naval auxiliary vessel *Fort Duquesne*, while in Canada the Government supply vessel *C. D. Howe* was equipped with a Bell 47 for a voyage to the Eastern Arctic. It proved an invaluable guide in finding a passage through the ice-pack and, as a result, hangar and flight deck accommodation for two similar aircraft was incorporated in the ice-breaker *D'Iberville*. Another new vessel which contains provision for helicopter landings and take-offs is the Royal yacht *Britannia*.

The whaling industry has undoubtedly provided the seaborne civil helicopter with its most important opportunity to date. One of the foremost helicopter pilots, Alan Bristow, had this to say in a lecture before the Helicopter Association last October. "It is not surprising that prior to the use of helicopters in 1950-51, the experience of whaling companies with aeroplanes in the Antarctic was disastrous. There was a legacy of 'mistrust' in flying machines in general, and on my first Antarctic expedition with the Hiller 360, I thought it had been passed on to helicopters in particular. One of the most difficult, if less tangible obstacles, has been to overcome the reluctance of whalers to accept the potentialities of the helicopter. . . . Whalers had to be convinced, and I am pleased to say that they now accept the helicopter as a robust, reliable and effective piece of equipment which, in the hands of experienced and trained personnel, can be used to their advantage and to the advantage of the industry as a whole."

During the last whaling season, he added, one S-51 sighted 1,334 whales in the course of 185 hours flown during the first 36 days of the season. Assuming one animal killed for every two sighted, the value of the catch could be conservatively assessed at over £600,000. When equipment for airborne killing and inflating of whales becomes available one helicopter will be capable of replacing four catcher vessels.

Such a step, Mr. Bristow points out, would transform the industry "at a time when present whaling costs make it hardly worth the gamble of sending out an expedition to the Antarctic." He concludes that "the experimental phase is over, and helicopters are in the whaling industry to stay."

Cable-laying by helicopter was first demonstrated in January 1952, when this Pest Control Hiller enabled a 1,250ft power line to be laid across a valley in the Malvern Hills, thereby avoiding destruction of some hundreds of trees. The helicopter's cable drum can be clearly seen.

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DOMAIN of the HELICOPTER

Raoul Hafner's Blériot Lecture: A Comprehensive Survey

Mr. Raoul Hafner, A.F.R.Ae.S., is chief designer to the helicopter division of the Bristol Aeroplane Co., Ltd.

IN Paris on Wednesday last, March 10th, the Royal Aeronautical Society's seventh Louis Blériot memorial lecture was due to be given by Mr. Raoul Hafner, A.F.R.Ae.S. Entitled *The Domain of the Helicopter*, the paper reviews the historical development and fundamental design-principles of rotating-wing aircraft, and analyses their configurations, performance and economy.

It appears certain that Mr. Hafner's lecture will be regarded as a most significant contribution to helicopter knowledge, and the reporting of it in this special issue of *Flight* is therefore particularly appropriate. Particular attention has been paid, in the abridged version which follows, to Mr. Hafner's considerations of rotor systems, of the three basic types of helicopter (in which a novel convertible helicopter is described) and of the helicopter in civil air transport.

After being introduced by Mr. Hafner, the lecture was to be read, in translated digest form, by M. Morian, chief engineer of the S.N.C.A.S.O. helicopter division.

It is noticeable that the author of the paper has been characteristically reticent about his own achievements in the field of helicopter design, which he first entered as long ago as 1927. In collaboration with J. B. Coats, he produced the R-1, which flew in Austria in 1930, and the R-2, which he brought to this country in 1933. Two years later the Hafner ARIII gyroplane appeared; though not a true helicopter, it introduced the now-established system of control by cyclic and collective pitch. His recent work with the Bristol Company—he joined them in 1944—is well known.

Historical Introduction.—The paper began by giving a short summary of the historical development of the helicopter. It first traced the development of human flight through the ages, and the successive emphasis laid on the three types of wing, flapping, fixed and rotating, with which it was thought this could be achieved. While Nature achieved success solely with the flapping wing, man successively tried all three. Successful controlled flight, however, came with the application of the fixed wing. But this led progressively to the large, modern aircraft with its principal dangers and limitations of high speed and the need for elaborate ground facilities.

The rotating-wing development had continued slowly in parallel with fixed-wing progress, and apparently initially with little success. Several helicopters were built from the earliest days, Juan de la Cierva successfully proved the Autogiro configuration; and, finally, in 1936 and 1937, the Breguet-Dorand and Focke-Achgelis demonstrated helicopter practicability. It remained for Igor Sikorsky in 1939 to achieve the production and application of the helicopter on a commercial basis.

After comparing these developments with the "fantastic performances" of modern fixed-wing aircraft, Mr. Hafner outlined the major disadvantages of the latter, and indicated the possibilities of the helicopter for transport over the shorter routes.

The Korean war had finally proved the helicopter's worth, and it remained now to apply, by practical design and operation, the lessons learned. The main purpose of the lecture was, in the light of this, to define the domain of the helicopter.

To avoid confusion which might arise owing to the great variety of terms applied to the helicopter, Mr. Hafner gave the four definitions which we quote below, and which he proposed not as new terms for general use, but to establish some basic definitions for use in his paper. He defined a helicopter as an aircraft heavier than air, capable of sustained hovering and embodying wings, which (at least during the period of hovering) rotated in a free airstream, and thus supplied substantially the total lift support. He then gave the following definitions:—

Pure Helicopter: a helicopter the wings of which rotated in a substantially horizontal plane and, throughout the flight, supplied the aerodynamic forces for sustentation and propulsion.

Compound Helicopter: a helicopter the rotating wings of which supplied at all times during flight the major part of the lift, but which in addition embodied substantially aerodynamic components, such as wings and/or airscrews that, mainly at higher translational speeds, supplemented the action of the rotating wings.

Convertible Helicopter: a helicopter capable of conversion during flight, such that the total lift was substantially transferred from the rotating wings to other wings, and *vice versa*.

Rotor Systems.—The rotor system of a helicopter comprised the rotors, their hubs and control mechanism and, in the case of shaft-driven helicopters, that part of the transmission which joined the rotors together. The rotor system was driven by one or more power units through branches of the transmission, with a freewheel in each branch, located preferably at the point of juncture with the rotor system.

The rotor system was *the* critical department in the helicopter. It had been said that the predominant hazard of the fixed wing lay in its high minimum flying speed which, combined with bad visibility or a power failure, was liable to lead to serious consequences. The hazard in the helicopter, on the other hand, was the mechanical complexity of the rotor system.

There was, however, no collective safety in a number of rotors. We could not afford to lose one rotor—or even one blade—and expect to continue to fly safely with the remainder. The rotor system was like a chain—if one link failed, the whole failed. Therefore, everything else being equal, the fewer rotors and blades there were in a rotor system, the greater was its safety.

As with the fixed wing, so the rotating wing was exposed to two types of loading: a limited number of applications of extreme load and frequent applications of medium load. It was thus necessary to establish on the one hand an envelope of ultimate load conditions where the material might be stressed close to the proof stress figure, and on the other hand to establish the so-called fatigue envelope, for which there was a much reduced safe stress level. The ultimate stresses arose generally from manœuvre and gust loads, but as these were always coupled with inertia effects such as blade oscillations or torsional oscillations in the transmission, their evaluation was made somewhat difficult. Even more complex were the loading systems that produced the fatigue stresses, for these were due mainly to fluctuating air loads on the blades or torque fluctuation in the engines.

Besides the problem of stress in the rotor system, there was that of wear in bearings and other detail components. These considerations *in toto* had pointed to the inadequacy of purely theoretical work alone and had, in consequence, led to a procedure of ground testing in which the flight conditions were simulated with as much accuracy as was possible.

Rotor Control.—The rotor provided not only lift but also control of the helicopter. This must necessarily be so because the rotor blade was the only aerodynamic surface which maintained high speed in all flight conditions, including hovering, and was therefore capable of receiving aerodynamic forces adequate for the purpose of control. We must, however, distinguish between the rigid and the articulated rotor. At its hub, the rigid rotor could render a force—the rotor thrust—as well as three independent moments—the rotor torque and two transverse moments. On the other hand, the articulated rotor could, apart from the rotor torque, produce three forces—the thrust and two transverse component forces. Rotation of the rotor axis produced in the rigid rotor a gyroscopic moment of considerable magnitude which was transmitted to the aircraft body. In the articulated rotor this gyroscopic moment was balanced by an aerodynamic moment, and no transverse moment was transmitted through the rotor hub.

The articulation of rotor blades had been found to overcome many of the difficulties which beset the early helicopters and, since the successful performance of the autogyro demonstrated the value of articulation, it had been adopted almost universally in helicopter engineering. The following considerations of various forms of control applied therefore only to the articulated rotor:

DOMAIN OF THE HELICOPTER . . .

Control Through Rotor Torque.—The rotor torque was a function of rotor speed and the mean blade incidence during rotation, i.e., collective pitch. As the rotor speed could not be varied quickly enough for control purposes, variation of the collective pitch remained the only means of varying the torque. With this variation there was, however, an unavoidably connected major variation of rotor thrust.

Control Through Rotor Thrust.—As mentioned, rotor thrust was varied by the collective pitch of the rotor. If, then, the rotor speed was maintained constant, the collective pitch became an express control of rotor thrust. Such thrust variation was, however, associated with rotor torque variation—the argument being an inversion of the previous one—and consequently simultaneous adjustment by other suitable controls was necessary.

Control Through Rotor Thrust Angle.—The rotor thrust vector acted substantially at right angles to the tip-path of the rotor, and tilting this plane in relation to the aircraft body would cause a corresponding tilt of the thrust vector. The tilting of the tip-path plane was effected by the cyclic or azimuth control.

Even although the articulated rotor could—apart from rotor torque—only render forces at the rotor hub, it could nevertheless be employed effectively for the moment control of the helicopter. There were only two cases:

(*a*) *Moment Control Through Collective Pitch.*—If a rotor was located in a manner such that its thrust vector substantially passed through the centre of gravity of the aircraft, then a variation of this thrust would have no moment about this point. If, however, there was a considerable lever arm of thrust vector about the c.g., then a change of thrust would be accompanied by a considerable change of moment.

(*b*) *Moment Control Through Cyclic Pitch.*—Similarly, if a rotor hub was placed at or near the centre of gravity of the aircraft, then a tilt of the tip-path plane relative to the aircraft body would produce only a change in the balance of forces; it would not produce a material change in the moments. But if the rotor hub was placed at a considerable distance from the c.g., then a change in the direction of the rotor thrust vector would produce a substantial moment about this point.

Transmission of Power.—Power transmission might take many forms and even in helicopter engineering a variety of proposals had been made. These ranged from the orthodox mechanical transmission to "gas shafts," between, on the one hand, a gas generator and a jet in the tip of a rotor blade, or on the other hand, a gas turbine converting the gas power into shaft power. Nevertheless, the author was convinced that the mechanical transmission would stay with the helicopter for some time to come, simply because it was, for all but the largest rotors, the lightest and most efficient form by which power could be supplied in the form needed at the rotor.

Investigations had shown that the optimum transmission speed for power shafting was between 3,000 and 4,000 r.p.m. In order to achieve the lightest transmission of power it was therefore necessary in the first instance to convert engine speed to the optimum transmission speed in a gearbox close to the engine or, preferably, directly attached to it. At the other end of the power transmission—the rotor head—a second speed conversion, which was made in another gearbox, preferably forming one assembly with the rotor head, reduced transmission speed to rotor speed.

Rotor Configuration.—In the following survey of the various rotor configurations attention was focused in the first instance on the need for the balance of forces and moments on the aircraft, secondly on its control and stability under various conditions of loading, thirdly on certain aerodynamic considerations relating to performance, fourthly on weight, and finally on the complexity of the transmission and similar factors.

At the outset the differences between the tip-driven and the shaft-driven rotor must be recognized. The tip-driven rotor was torque-balanced within itself and only rotor thrust was transmitted to the aircraft body. The thrust vector of such a rotor could be made to balance the weight of the aircraft if the rotor was placed directly above the centre of gravity, and this simple arrangement achieved the full equilibrium of forces and moments. As regards control, varying the magnitude of the rotor thrust vector produced (1) a vertical control force; a tilt of this vector in the longitudinal plane produced (2) a force in this plane; and a lateral tilt produced (3) a lateral force. If the hub was placed above the aircraft c.g., then the longitudinal and lateral components of tilt of the rotor thrust vector would also produce (4) a pitching and (5) a rolling moment respectively. There remained only the yawing moment. In a small helicopter this could be obtained conveniently by placing a control surface in the form of a rudder within the slipstream of the rotor.

Driving at the blade tip therefore permitted the construction of a true single-rotor helicopter, and indeed it was the only practical form of single rotor helicopter. In respect of c.g. travel, however, the single rotor helicopter was necessarily rather limited. The tip-driven rotor had, nevertheless, a marked advantage on the score of weight. It had been shown that the weight of a rotor blade was controlled by the coning angle, and large rotor blades particularly must be mass-balanced at their tips. This parasitic weight could be avoided if the power unit was placed there also.

Just as tip drive was natural to the single-rotor helicopter, so mechanical drive was natural to the multi-rotor helicopter. This conclusion was supported by the following reasoning:

(a) Rotors were subject to limiting flight conditions. From this it was obvious that a multi-rotor helicopter would achieve the widest flight envelope when its rotors were so devised that their limiting conditions were reached simultaneously.

(b) This was best achieved by turning the rotors at a rate such that their tip speed was the same.

(c) This was best achieved by a mechanical interconnection in the form of shafting and suitable gearing.

(d) It had been shown that the simplest rotor control was based on a variation of blade incidence, with the speed kept substantially constant. As in a multi-rotor helicopter all rotors were utilized for control purposes, the maintenance of constant speed in the whole rotor system was most desirable.

(e) Such a transmission could be linked, at little additional expense in weight and complexity, with one or more sources of power.

In shaft-driven multi-rotor configurations the balance of forces and moments was more complex than in the single rotor. An infinite number of combinations of vectors and moments was possible, but all these combinations fell into two groups:

(a) Torque-balanced or twin-rotors. These were rotors with torque vectors which added up to zero, and (b) others.

From the latter group only one form had come into prominence. This consisted of one large rotor supporting the whole weight of the aircraft, and a small rotor aft of the main rotor, producing a relatively small lateral thrust which, in conjunction with a large lever arm, balanced the main rotor torque. There were small additional forces and moments necessary in order to complete the balance and it was evident that the force and moment diagrams were unsymmetrical and rather complicated. In particular a small change in any of the forces or moments, such as was caused by normal disturbances in flight, required adjustment almost all round and, as a result, this type of helicopter was more difficult to fly, for human and automatic pilots, than were symmetrical types.

The necessarily different speeds of the unequal rotors produced a wider band of excitation frequencies than applied with either a single rotor or equal rotors, and this increased the difficulties of avoiding resonant conditions. On the score of rotor weight there was also a penalty, because two rotors of different size weighed more than two equal rotors capable of carrying the same weight.

There were various forms of torque-balanced twin rotors. Besides being equal in torque they were generally identical in other respects (lift, diameter, speed), but rotated in opposite directions. We distinguished between eclipsed and non-eclipsed rotors. Eclipsed rotors were either concentric or they were closely intermeshing. The balance of forces and moments in this configuration was like that of the single rotor, except that in the former case torque (and thrust) could be increased in one rotor and decreased in the other (the total rotor thrust remaining constant), so producing a net rotor torque which could be used for yaw control.

There were two forms of non-eclipsed twin-rotors and both had been tried. The first was the side-by-side arrangement and the second was the arrangement in tandem. In both configurations the rotors had the full benefit of the total disc area in the hovering condition, but, as a *quid pro quo*, the transmission system was more extensive and heavy than that involved in eclipsed rotors.

It would be seen that whilst these configurations, like all twin-rotor configurations, were symmetrical with respect to the normal direction of flight, the control was substantially different from that discussed previously. There was now an "axis of suspension" connecting the two rotor hubs and the two thrust vectors, the centre of gravity of the aircraft lying below this axis.

A considerable c.g. travel along the axis of suspension was permissible without seriously upsetting the balance of the aircraft. This represented a major advantage for the tandem helicopter over the other configuration, particularly as it could be arranged that the "axis of suspension" ran with the fuselage major axis.

Whilst the aerodynamic performance in hovering was the same, there was a significant difference in forward flight between the side-by-side and the tandem configuration. The former had a large "wing span" over the two rotors and consequently its induced losses were relatively low, whereas the latter, with only half the span of the former, had a higher induced flow. Against this, allowance had to be made for the considerable weight and the parasitic drag of the lateral outrigger structure which side-by-side rotors required, whereas in the tandem arrangement the rotor supports were light and had negligible drag.

The author believed that the increased complexity and the consequently reduced safety-standard of configurations involving more than two rotors were not acceptable, as these types could offer no material advantages over the two-rotor configurations.

Power Supply.—After discussing the power requirements for hovering, cruising and take-off (see Fig. 1), and the technique of

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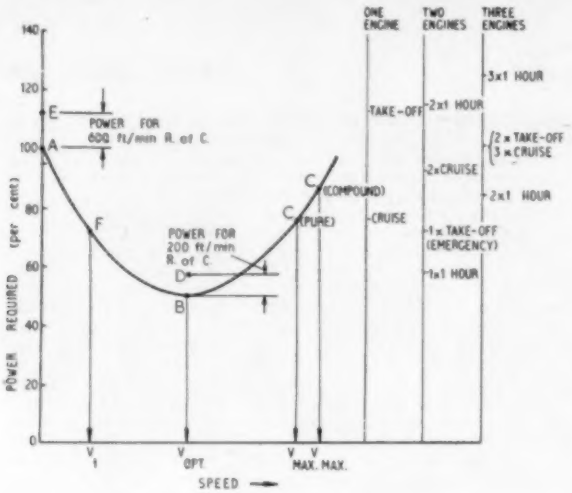

Fig. 1 (left). The power requirements of a pure helicopter of moderate cruising speed, expressed as a percentage of that needed for hovering and shown with variation in speed.

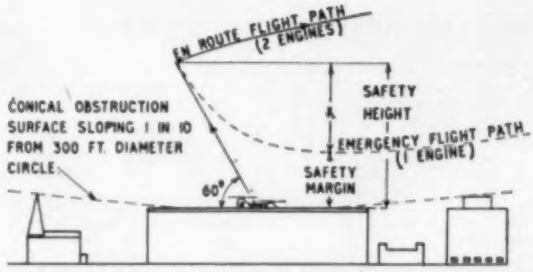
EN ROUTE FLIGHT PATH (2 ENGINES)
CONICAL OBSTRUCTION SURFACE SLOPING 1 IN 10 FROM 300 FT. DIAMETER CIRCLE
SAFETY HEIGHT
EMERGENCY FLIGHT PATH (1 ENGINE)
SAFETY MARGIN
60°

Fig. 2 (above). The procedure for backward take-off at 60 deg, intended to reduce the danger of engine failure after take-off in a built-up city area.

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backward take-off (Fig. 2), Mr. Hafner considered the various types of power unit in helicopter use.

Those used for tip drive were:

(1) The ramjet and the pulse-jet. Both these engines were extremely light, partly intrinsically and partly because they replaced blade ballast. On the other hand, their fuel consumption was very high.

(2) The pressure jet. This had a lower fuel consumption but was heavier and more complex in its installation.

(3) Turbojets. These units had been proposed for installation at the rotor blade tip, not only for large slow-rotating rotors, but also for smaller ones. Such an arrangement combined the advantages of low weight, simplicity and low fuel consumption, but the main difficulties were in the high centrifugal and gyroscopic forces to which the engines were exposed.

The power forms for shaft-drive were:

(1) The piston engine combined with a clutch. This power unit was economic in consumption, but was heavy and involved complexity in installation. The power characteristics of the piston engine did not, unfortunately, suit the helicopter and this incompatibility was aggravated in multi-engined types.

(2) The free gas-turbine. This engine had higher fuel consumption than the piston engine, but it was lighter and its installation was much simpler. Its main advantage, however, lay in the fact that the only driving connection between the power producer (the gas generator) and the rotor-driving turbine was the gas stream. Not only did this eliminate the clutch of the piston engine, but it also served as an infinitely variable gear reduction over a useful range of speed ratios, without appreciable loss in efficiency.

A consideration of weights and fuel consumptions for various types of power plant (see Fig. 3) showed that the light tip jets had the advantage in short-range flying, whereas the elaborate but more economic installations were superior for the longer ranges.

The Three Basic Types.—Turning to the three basic types of helicopter defined earlier in his paper, Mr. Hafner proceeded to describe the distinctive features of these respective machines:

The Pure Helicopter.—This type of machine relied wholly on its rotors for sustentation as well as propulsion. The weight-carrying rotor or rotors remained substantially horizontal and the axial component of airflow was never very large. The critical limitations of the rotors were in the tip speed and the tangential advance ratio. The top limit was formed by that forward speed corresponding to the highest tip Mach number that could be achieved without the development of shock. The low-speed limitation resulted from the stalling of the rotor blade, which depended on the blade loading factor. The practicable maximum cruising speed, in the case of the typical pure helicopter, was of the order of 247 ft/sec = 146 kt at sea level.

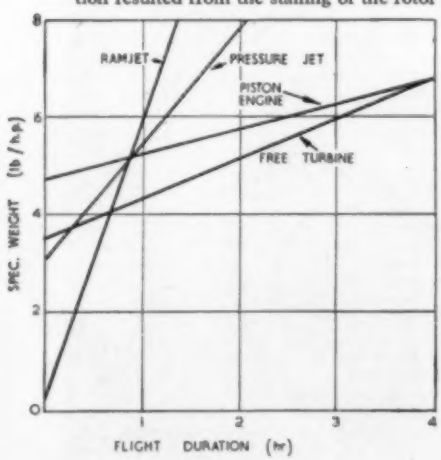

Fig. 3. Specific weight (total weight of power plant installation and of fuel consumed per maximum continuous h.p.) against flight duration, for various types of power plant.

There were, however, other limitations which had to be considered. A study of these factors showed that compromise had to be made between the conflicting desiderata, and much depended, therefore, on the specification against which the project was made. Thus, for instance, a single-engined helicopter must have a satisfactory autorotating performance to permit forced landings to be made. This requirement restricted the disc-loading and, to some extent, the blade loading and the tip speed. In multi-engined helicopters, however, where this argument did not arise, the optimum disc-loading was of the order of 6.0 lb/sq ft.

Summing up, it could be said that the speed envelope of the pure helicopter was controlled mainly by, (a) the design of the blade tip and, (b) the blade loading, and speed increases beyond certain limits were bought at progressive expense in power.

The Compound Helicopter.—There were many forms of compounding the rotor with other aerodynamic devices in order to advance the performance of the helicopter, but by far the most effective means was the stub wing. Such a wing had no effect at hovering or during slow-speed flight, but as speed was gained it progressively supplemented the rotor thrust until, at a given maximum speed, a worthwhile percentage of the all-up weight was taken by the wing, the rotor being correspondingly unloaded. The effect and the value of this action could be studied by reference to the previous example of the pure helicopter. If it was now assumed that a given stub wing was capable of carrying one half of the a.u. weight of the pure helicopter, at its maximum design speed, then the blade loading factor was reduced in this flight condition to half the previous limiting value.

Thus the speed of the helicopter was increased without change either in the rotor blade area or rotor profile power. The rotor coning angle was also reduced and this diminished vibration; alternatively it would permit a reduction in blade weight.

On the other hand, if no speed increase was desired, the stub wing could be used to enhance the economy of the helicopter, as it then permitted an *increase* of the blade loading factor by two, without ill effect, but with the advantage of a reduction in profile power. Allowance must be made, on the debit side, for the drag and the weight of the fixed wing. There was, however, a certain net gain, because the fixed wing was more efficient in the production of lift at speed than was the rotating wing, and by mounting the undercarriage to the wing a considerable weight saving was achieved.

There were, nevertheless, certain limits which must be observed in the unloading of the rotor. The helicopter was basically controlled in flight through its rotor, or rotors, and a loss in rotor thrust meant a loss in some of its control. If, therefore, the rotor unloading assumed considerable proportions, it was necessary for the rotor control to be supplemented by a wing control.

In addition, there was the problem of propulsion. In a pure helicopter, sustentation and propulsion were obtained together by a small forward tilt of the rotor vector. Compounding the rotor with a stub wing would, however, decrease the rotor lift whilst at the same time increasing the aircraft drag. This meant that the rotor thrust vector had to be given a considerable forward inclination which, at a certain stage, began to introduce aerodynamic complications. These difficulties might to some extent be delayed by additional compounding with an airscrew or with a turbojet. A high degree of rotor unloading might sometimes be combined with a reduction of rotor speed in order to reduce rotor profile power; this, however, produced high advance ratios and, with them, the danger of reversed flow flutter.

The Convertible Helicopter.—Although enthusiastic supporters of the convertible helicopter had been active for some time, serious endeavours in this field with a chance of practical success were a comparatively recent development. There was wide scope for

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imagination and invention among the many possible forms of convertible helicopter, but despite this diversity one could distinguish only two major types, and two forms of conversion:

Type 1: The rotating wing was transformed during conversion into a fixed wing and sustained at all times the weight of the aircraft.

Type 2: The rotating wing was released during conversion from its function as a support of the aircraft, and this function was transferred to a fixed wing.

Form 1: The conversion did not involve major linear and angular accelerations, i.e., it consisted of a succession of quasi-static flight conditions.

Form 2: All other conversions.

Briefly it might be stated that the convertible helicopter was potentially capable of establishing itself in a certain sector of the air transportation field, *provided the technical problems of conversion could be solved in a simple and practical manner.* This, indeed, was the premise for the inclusion of a convertible helicopter in the comparative analysis in the next section of the paper, which was mainly concerned with the question of the practicable worth of such aircraft. Another rather tentative conclusion concerned the optimum type of convertible helicopter. The author believed that one of the most promising forms (see Fig. 4) would comprise a more or less standard aircraft body, a pair of relatively small fixed wings designed to give optimum performance at cruising flight, engines mounted near the wing tips and driving two rotors—but also interconnected to form *one* transmission system, as in conventional helicopters. The rotors would sustain the weight of the aircraft in the hovering condition of flight when the longitudinal axis of the aircraft was vertical, and act as airscrews in the cruising condition of flight when this axis was horizontal; thus the aircraft as a whole, rather than one part of it, would be rotated.

The conversion from one extreme flight condition to the other would be slow or quasi-static. Thus when converting from the hovering condition, the aircraft axis was at first slightly inclined in the normal plane of the aircraft, which caused a horizontal component of the rotor thrust. This gradually accelerated the aircraft horizontally, and the attainment of a small horizontal velocity, together with the induced velocity, resulted in an airflow which produced a small normal force on the wing in a direction opposite to the motion, that is to say, a small vertical component was introduced. A further tilt of the aircraft increased the horizontal velocity and caused a greater force on the wing so increasing the vertical component. This force grew until the reaction on the wing was vertical and equal to the aircraft weight. The aircraft would then fly at high speed and with its axis in the direction of flight. The conversion back to helicopter flight was the reverse of this process.

It could be shown that a high induced velocity in the hovering condition was necessary in order to avoid stalling of the wing during the conversion, i.e., the disc-loading must be high and the rotor diameters were consequently small. For this reason the power-required curve of this convertible was much higher at the hovering point than that of the conventional helicopter. In order to meet this power characteristic, the power installation of such a convertible would be preferably comprised of free-turbine power units—one pair on each side and of such power that, if necessary, any three units could sustain the aircraft during hovering (for reasons of safety). For normal cruising flight only two engines need be used (at their optimum cruising power) ensuring a low fuel consumption. The aircraft was provided with two pockets in its wings representing strong points capable of carrying the weight of the aircraft. Rotor control was used both during hovering and cruising flight, but was supplemented by certain fixed-wing controls. In cruising flight the pilots lay in a prone position, whereas during hovering they stood upright, the cockpit (situated in the nose of the aircraft) being in this condition somewhat akin to a circular bridge of a ship. The passengers were seated in rotatable seats which automatically maintained a level attitude during the process of conversion.

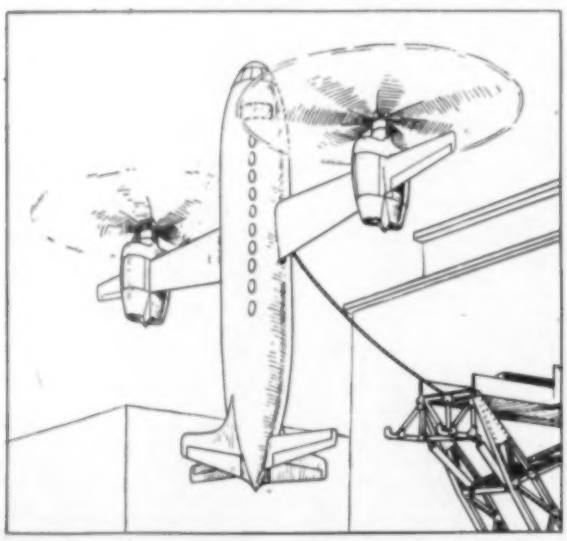


Fig. 4. A convertible helicopter, of the type suggested by Mr. Hafner, hovering near the gantry used for landing and take-off.

The landing gantry comprised fittings, not unlike railway buffers, which contained shock absorbers, able to yield in all directions, and which fitted the pockets in the wings of the aircraft. The helicopter approached the gantry in the hovering attitude until it came to within 50 yd of it. A steel cable was then lowered from a specially designed power winch, fitted at the c.g. of the aircraft, and was attached to an anchor point on the gantry. The pilot thereafter continued to hover the aircraft, which was then winched in towards the gantry until the spring buffers registered in the pockets of the aircraft.

The aircraft having been safely secured to the gantry, its engines were stopped and it was then rotated by a small ram into the horizontal position, after which unloading could commence. A converse procedure applied to the take-off.

There remained the question of comfort. The rotation of the aircraft during take-off and landing might be considered an unpleasant or even frightening experience for passengers. Linear and angular accelerations, however, were almost nil and certainly less than those in a conventional take-off. The speaker believed therefore that there could be only psychological reasons for discomfort, and these would disappear with increasing familiarity. In other points the comfort of the convertible was good. There was virtually no vibration in forward flight, and in hovering only during conversion, and the use of large low-speed rotors (or airscrews) and turbines would mean noticeably little noise.

Civil Economics and Applications.—In order to assess the potentialities of the helicopter in relation to the overall field of civil air transport, the lecturer presented a comparison, in terms of economics, of a selection of eight hypothetical types of aircraft. These were in order of cruising speeds: (1) a pure helicopter, designed for best economy at low cruising speed; (2) a pure helicopter, designed for best economy at moderate cruising speed; (3) a compound helicopter, designed for the same cruising speed as for (2); (4) a compound helicopter, designed for higher cruising speed; (5) a convertible helicopter, designed for best economy at high cruising speed; (6) a propeller driven aeroplane, designed for the same cruising speed as for (5); (7) a jet driven aeroplane, designed to cruise at high subsonic speed; (8) a jet driven aeroplane, designed to cruise at supersonic speed.

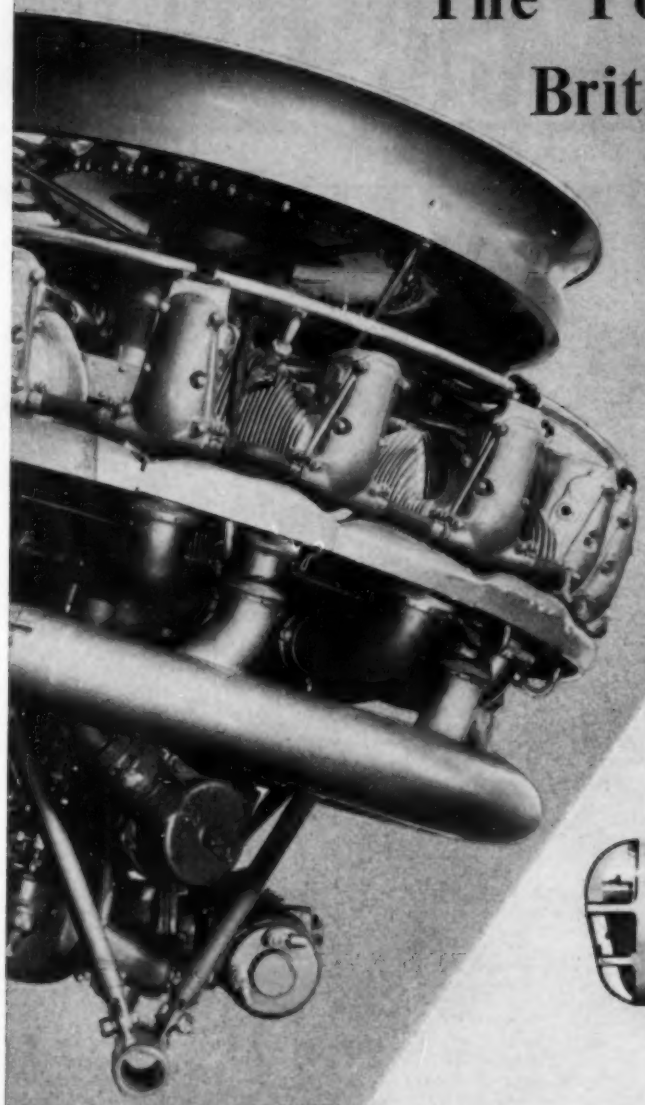
"Economics," said the author, "has been chosen as the yardstick; it is, after all, the rules of economics which, in the long run, ordain the balance in the diverse activities of our society."

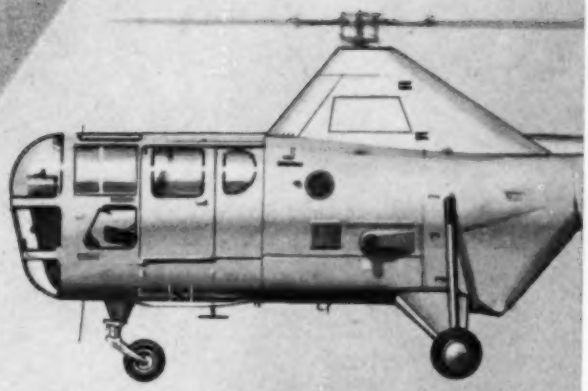
An all-up weight of 50,000 lb had been fixed as a common factor in this family of aircraft, for by this means most of the significant differences which otherwise would have been hidden appeared explicitly in the analysis. This was a compromise: the optimum weights of the aircraft considered would vary approximately in the order shown from a pure helicopter at 30,000 lb to the supersonic long-range aeroplane, which appeared to be "still too small at 200,000 lb."

Equal standards of design and production had been assumed for all types. The scale of production was in each case assumed to be 100 units, and performance estimates for the helicopters were in agreement with formulae given earlier in the paper; those for the aeroplane were derived by standard performance methods. Assumptions made included: 2,000 hr annual utilization; 75 per cent load factor; ability to complete flight in the event of one engine failing *en route*; insurance rate, 9 per cent per annum; aircraft economic life, eight years; cost of fuel (gas turbine oil), 2s per gallon; crew costs, £6 per hour; headwind allowance, 30 kt for the aeroplane and the convertible helicopter, 4 kt for the other helicopters.

In assessing the first cost of aircraft the author used a simple method dividing the empty weight of the aircraft into four basic categories representing different kinds of engineering, each with its own supply curve defined by the cost of production: air-frame equipped; power plant complete; propeller or rotor hubs, gearboxes or shafting; propeller or rotor blades. From the resulting supply curves the author prepared a similar curve for a whole helicopter, allowing for prototype and development costs. This showed a figure of just over £8 per lb empty weight for a typical British helicopter, assuming production of 200 units, compared with a corresponding figure estimated at £15 for American-built helicopters. The lecturer showed the effect on operating costs and journey time (Figs 5, 6) of the helicopter's use of rotor stations

The Power Unit for British Helicopters





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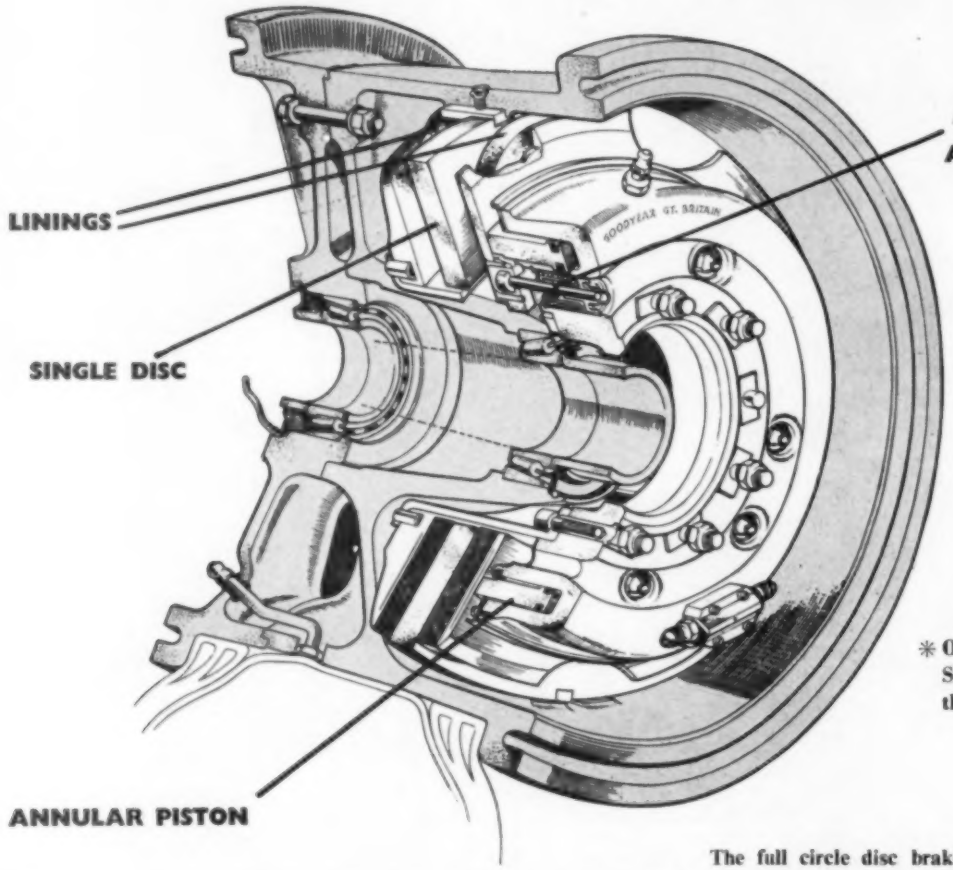
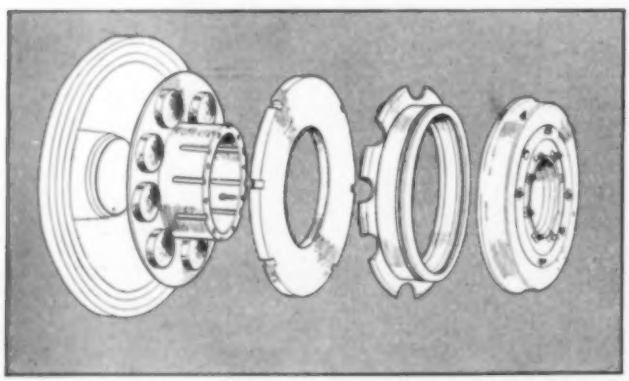


* Only Goodyear provide Single Disc brakes for the 'Viscount'.



Exploded view of the Full Circle Disc Brake

The full circle disc brake offers much longer service life — gives very even torque and is contained completely within the wheel width. This new type brake — developed from the famous single disc brake after years of research — is already in airline service, enabling operators to carry greater pay loads at less cost.

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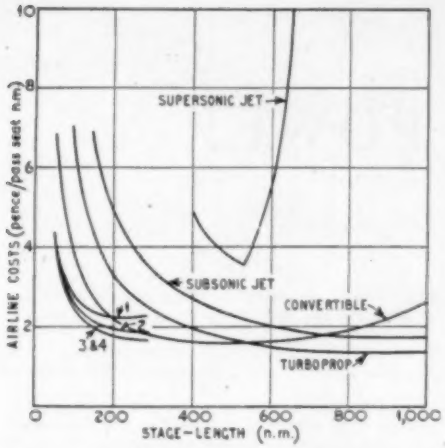


Fig. 5 (left). Comparative costs in airline operation. Helicopter types indicated in the numbered curves are (1) low solidity, (2) high solidity, (3) low-solidity compound, (4) high-solidity compound.

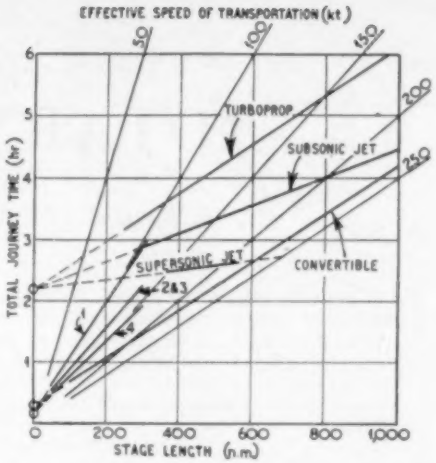


Fig. 6 (right). Comparative journey-time. Helicopter types indicated by the numbered curves are as in Fig. 5.

DOMAIN OF THE HELICOPTER . . .

situated in the centres of towns. The transit of passengers and luggage through these rotor-stations was assumed to be similar to that at railway stations with no advance booking, tickets being bought at the start of the journey. It was justifiable, he urged, to assume that helicopters would carry less fuel reserves than those for fixed-wing types: *viz*, supersonic aeroplanes, 0 miles for diversion plus ¼ hr holding; subsonic aeroplane, 300 miles for diversion plus ¼ hr holding; helicopter, 20 miles for diversion plus ¼ hr holding.

Methods of computing direct costs corresponded closely to those proposed by B.E.A. and the S.B.A.C., both of which the author included as appendices to the paper. Typical airline costs had been computed from information supplied by B.E.A. The contracted and simplified operation possible from rotor-stations produced annual, hourly and landing costs for a typical 50,000 lb helicopter of respectively £40,000, £6.7 and £4.6 compared with costs of £45,000, £6.7 and £68 for a 50,000 lb aeroplane.

Discussing the results of the comparison, the author said it was evident that for short-haul journeys the slow helicopters were much faster than the fast aeroplanes. A turboprop and subsonic aeroplane were in their element for journeys from 1,000 miles upwards. The convertible helicopter appeared to be capable of combining the advantages of the helicopter with those of the aeroplane. In terms of comparative journey cost the supersonic aeroplane was not competitive at any stage-length. The subsonic jet aeroplane could not compete with the turboprop aeroplane and the combined helicopter was notably better than the pure helicopter. The convertible helicopter had no rival between 200-530 mile stage-lengths.

The factors of convenience and comfort, although economically imponderable, had significant economic factors. One of the most irritating experience in conventional air journeys was the change from coach to aircraft and then back to another coach.

There was no doubt, the paper went on, that avoiding changing on a journey greatly enhances the comfort, apart from reducing the risk of lost luggage or similar mishaps. It was difficult to assess the value of comfort, but he personally would be prepared to pay the bus fare for the privilege of *not* having to use the bus.

The lecturer went on to establish some of the many highly specialized duties for which helicopters were proving particularly suitable—such as cable-laying, pipeline surveying, fire fighting and flood rescue—and described what were the special reasons underlying the use of a helicopter in such rôles. For example, the helicopter might make possible the saving of a few minutes in time which, in certain circumstances, might be of such value as to justify the operating costs incurred; or it might be that ground facilities were such that no other means of transport could be found to undertake a particular job.

Summing-up, it might be recalled that, although the rotary-wing aircraft had originally appeared to offer more promise than had the fixed wing, the relative simplicity of the latter type of aircraft had caused it to be the first to reach fruition, at the expense of other lines of development. Now, the rotary wing was once more of general aeronautical interest, and it appeared likely that various forms of helicopter would eventually handle the vast volume of traffic on journeys of up to 500 miles.

On short-haul work the helicopter was supreme, and the convertible helicopter could successfully challenge the fixed-wing airliner on stages up to about 530 miles. On a city-centre to city-centre basis, the convertible aircraft was effectively faster than an aircraft cruising at Mach 2; in fact, there did not appear to be economic justification for the supersonic transport at *any* stage length. High speed transport would probably be achieved only outside the earth's atmosphere; until such developments materialized, the author concluded, we might expect a reasonable span of time during which we might apply some of our thoughts and energies to the helicopter; the rotating wing was revolutionary in the fullest sense of the word, and it demanded an imaginative and uninhibited approach.

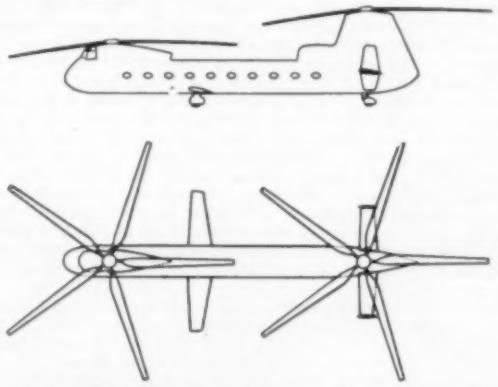


Fig. 7. Typical twin-rotor layout for short-haul journeys.

	Pure Helicopter (Low Solidity)	Pure Helicopter (High Solidity)	Compound Helicopter (Low Solidity)	Compound Helicopter (High Solidity)	Convertible Helicopter	Turboprop	Subsonic Jet	Supersonic Jet
WEIGHT BREAKDOWN (lb):—								
Equipped airframe	12,916	12,899	14,912	14,601	15,178	19,290	18,170	20,600
Blades	1,560	2,520	1,260	1,735	1,210	640	0	0
Hubs and transmission	5,025	5,200	4,250	4,490	2,282	740	0	0
Power plant	6,523	6,523	6,523	6,523	16,533	7,613	7,870	12,400
Crew	554	554	554	554	554	554	554	380
Disposable load	23,422	22,304	22,501	22,097	14,143	21,163	23,406	16,620
All-up weight	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
SPECIFIC COST (£/lb):—								
Equipped Airframe	10.0	10.0	10.0	10.0	10.0	10.0	10.0	16.3*
Blades	15.0	15.0	15.0	15.0	15.0	15.0	—	—
Hubs and transmission	5.0	5.0	5.0	5.0	5.0	5.0	—	—
Power plant	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Complete aircraft	9.33	9.50	9.45	9.50	9.87	10.0	10.0	14.37
FIRST COST (£):—								
Equipped airframe	129,160	128,990	149,120	146,010	151,780	192,900	181,700	336,000
Blades	23,400	37,800	18,900	26,000	18,150	9,600	0	0
Hubs and transmission	25,125	26,000	21,250	22,450	11,410	3,700	0	0
Power plant	65,230	65,230	65,230	65,230	165,330	76,130	78,700	124,000
Total cost	242,915	258,020	254,500	259,690	346,670	282,330	260,400	460,000

NOTES: Assumed production: 100 off. Prototype and development costs *not* included. *Machined skin.

ROTARY-WING POWER

A Review of Present Practice and Future Possibilities

IT is probable that, in the fulness of time, the present will be looked upon as the period in which rotating-wing aircraft "grew up." As other sections of this issue show, development contracts and large-scale production orders are now being placed for a variety of rotary-wing designs, the majority of which are intended to meet specialized operational requirements. Gone, at last, are the pioneering days when the helicopter was *only* a subject for experiment and "stunt" demonstrations.

Helicopters of sorts have been built, off and on, throughout the lifetime of this journal—say 45 years. For the first 40 of these years, their total production was minute, and nothing like the quantity required to warrant the development of special helicopter engines, designed *ad hoc* from the start. It is therefore understandable that rotary-wing airframes have in the past been built around engines which, if not quite the cast-offs from fixed-wing practice, have not necessarily been what the helicopter designer would have chosen had he had a free hand from the outset.

The propulsion of helicopters is a truly vast field. The terms of reference for a writer on rotary-wing power units cannot stop at "an engine" as such, for the choice of power unit is intimately related to the purpose of the aircraft, which influences the rotor-system employed and the type of power required. In fact, it is possible to employ a propulsive system extending throughout the aircraft, without any single item which could be called the engine.

As we have said, rotary-wing aircraft are in an adolescent stage. Anyone who doubts this should try to assign an operational class or purpose to most of the designs now flying in service; inevitably the answer has to be "miscellaneous," just as it was on fixed-wing aircraft before World War I. In every case the designer was originally concerned solely with the development of a successful flying machine, and those designs which have been rewarded with genuine mass-production—such as the Bell and the Hiller—have found favour simply because they could do work which nothing else could do with reasonable efficiency, and not because they were designed for a particular rôle.

The development of a helicopter is a lengthy and expensive process. The simplest basic layout, which was universally adopted in all the earliest production helicopters, is a single lifting rotor mounted, roughly over the centre of gravity of the aircraft, on a shaft turned by an engine mounted within the fuselage. Associated with this main rotor there must be some form of torque-reacting device to stop the fuselage itself from rotating, and to provide directional control; the preferred arrangement is the use of a long tail boom carrying a small high-speed rotor turning about a horizontal axis and driven by a shaft from the main engine.

This classical configuration is still much used, and serves well to introduce a description of present helicopter piston engines and shaft-drives, which must be taken as a starting point before considering the radically different systems of the future.

Most aircraft piston engines have cruising crankshaft-speeds of the order of 2,000 r.p.m. The rotational speed of the main rotor can be varied, according to the all-up weight, blade area and disc area, and other factors, but it will rarely exceed about 300 r.p.m. A step-down gearbox between the engine and rotor is, therefore, a necessity, and it can be mounted either on the front of the engine crankcase as in fixed-wing practice, or it can be mounted close underneath the hub of the rotor. The latter is a better arrangement, since it allows a simpler and more easily changed engine to be used, and also permits the use of a lighter drive shaft, owing to the higher r.p.m. and hence lower torque. The Bristol system shown in Fig. 1 is typical of British practice.

Use of a remote gearbox is by no means the only alteration that has to be made to a fixed-wing engine to fit it for helicopter work. The fact that the drive-shaft from the engine has to come out of the centre of the fuselage in a vertical direction tends towards the use of an engine so mounted that the crankshaft is itself vertical. In a radial engine—the type most frequently employed—this involves turning the engine on to its back.

The only fully-developed British helicopter engine is the Alvis Leonides, a nine-cylinder air-cooled radial, versions of which power the Bristol Sycamore and 173, Fairey Gyrodyne and Westland Dragonfly. The Gyrodyne has a unique engine installation (to be described later), but the other types each employ a vertical-crankshaft Leonides, in which the lubrication system has been completely redesigned with the sump on what was formerly the rear cover. Accessories, too, are in quite different positions from those in the "fixed-wing" Leonides; in fact, it is often advantageous to mount the major aircraft-system accessories on the rotor gearbox, where they remain operative in the event of engine failure.

The engine mounting for vertical-crankshaft engines usually consists of a built-up ring assembly attached to the crankcase, supported upon a welded steel-tube mounting carried by locally strengthened portions of the fuselage. Vibration-damping, exhaust systems, fire prevention, and similar subjects generally follow fixed-wing practice. Cooling, however, is particularly important, owing to the very low air-speed at which the engine may be required to give full power. In the Leonides, which can be taken as quite representative, the whole engine is closely cowled in an unstressed light-gauge sheet assembly, through which cooling air is forced in a downward direction by a fan. The cooling air enters at the top of the fuselage, ahead of the rotor hub, and passes out to atmosphere below and to the rear of the engine. The fan itself is driven at crankshaft speed, and is quite a sizable unit, having a diameter of 29in and 24 blades of forged light alloy.

In order that the engine may be readily started, and also to allow the rotor to autorotate in the event of engine failure, a clutch of some kind has to be insterted in the drive shaft. Almost invariably this unit takes the form of a simple single-plate clutch, controlled by centrifugal bob-weights mounted on needle bearings. A clutch of this nature capable of transmitting over 500 h.p. gets very hot, yet has to retain a high degree of rigidity and mechanical strength. In practice, the necessary mass of metal required is of some assistance in acting as a flywheel. The Leonides clutch is usually arranged to take up the drive at about 960 r.p.m.

In the drive shaft, it is common practice to fit a shear coupling, or weak link, that will operate in emergencies; this may be a flexible coupling connected by light-alloy bolts to a flange on the engine shaft.

Many of the features mentioned above in connection with the British Leonides are found in foreign helicopter engines, such as the American Pratt and Whitney, Franklin, Lycoming and Wright, and the French Salmson and SNECMA 14X-H. All these engines are highly-developed and they are proving adequate for their present tasks. But all suffer, to greater or lesser extent, from the omnipresent problem—their fixed-wing heritage. As far as power requirements are concerned one of the most fundamental differences between fixed- and rotary-wing aircraft is that, whereas a fixed-wing aircraft calls for a great effort for a short time (at take-off) followed by lengthy cruising at moderate powers, the helicopter is less concerned with short-time all-out power than with steady output at perhaps 90 per cent of the maximum possible.

Although it is not intended to constitute a precise picture,

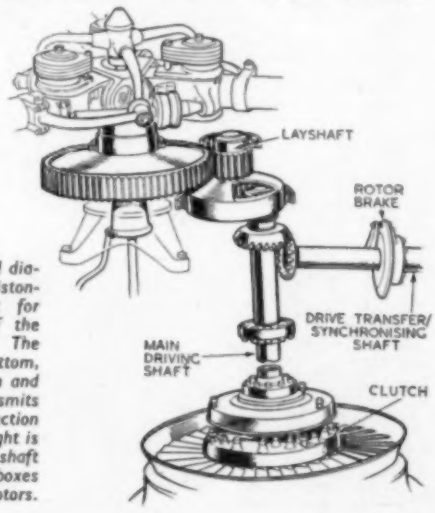


Fig. 1. A simplified diagram of a typical piston-engine drive—that for the front rotor of the Bristol 173 Mk1. The engine, at the bottom, drives a cooling fan and a clutch which transmits the power to the reduction gearbox. On the right is seen the end of the shaft connecting the gearboxes of front and rear rotors.

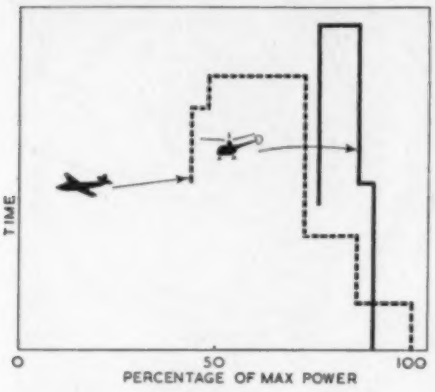


Fig. 2. This qualitative diagram shows the amount of time for which an engine is likely to have to operate at each power setting. As can be seen, the fixed-wing engine cruises at a lower output than does a similar engine in a helicopter, but a higher take-off power is needed.

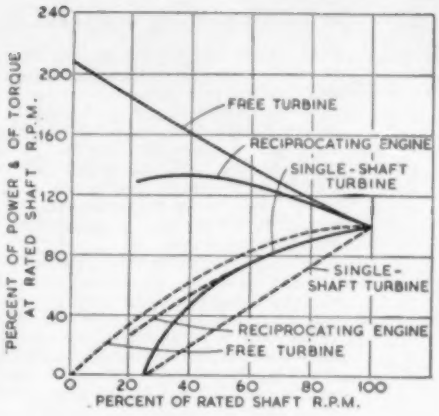


Fig. 3. Curves of power and torque for typical piston engines, single-shaft turbines and free turbines, plotted against r.p.m. The full lines denote torque; the broken line indicates power.

Fig. 2 does indicate the variance between a typical fixed-wing flight and a military helicopter sortie, from the aspect of length of time spent at each throttle setting. It is at once clear that the standard Air Registration Board type-test schedule, which is based on fixed-wing requirements, does not properly meet the case for the optimum helicopter power unit. At the Anglo-American conference last September, Capt. A. G. Forsyth, of the Fairey Aviation company, proposed a new schedule based on the maximum power which could be permitted for a one-hour period (with a reasonable overhaul life) and that the cruising ratings should be based on 85, 75 and 65 per cent of the revised one-hour rating. He pointed out that the helicopter Leonides, with a "take-off" rating of 560 h.p., had a current one-hour rating of but 455 h.p.; with the revised schedule the one-hour rating should be something like 92 per cent of the "5-minute" limit, i.e. 520 h.p. Capt. Forsyth's comments brought an assurance from Mr. Walter Tye, Air Registration Board, that the A.R.B. were drawing up a new test schedule.

In his paper, Capt. Forsyth went on to propose a completely new design of helicopter engine—a 12-cylinder horizontally opposed unit. There is no doubt that an engine of this layout is a better "fit" in a helicopter; for example it is possible to mount a flat-twelve engine in the fuselage roof close up to the rotor gearbox, and not only save transmission weight but also recover a great deal of useful fuselage volume. Another consideration of some importance is the fact that a tandem-rotor transport helicopter has to be of very great size if there is to be a passage-way joining the flight-deck to the passenger cabin. In the present Bristol 173, with a fuselage cross-section only slightly larger than that of the Sycamore, the nose compartment is isolated from the cabin; it could be argued that this is a disadvantage which might be rectified by the adoption of horizontally-opposed engines.

Mention of the Bristol company brings to mind the fact that the Bristol engine division actually designed and built a horizontally opposed, 12-cylinder, sleeve-valve engine for the Bristol 171 (later Sycamore). Many will regret the abandonment of this project—a decision taken after carefully weighing up the expected future development of helicopters, and after examination of the characteristics of shaft-drive gas-turbine engines, of which more will be said.

The problem of cooling a helicopter piston engine can be very severe, particularly in the hovering case. One of a number of little-known Fairey engines was the P.12, of the immediate pre-1939 era, which was a horizontally opposed 12-cylinder engine with liquid cooling. Installed in a helicopter it was hoped to give economical and quiet running, the reduced fuel consumption outweighing the increase in installed weight for block-times exceeding three hours. But here again difficulty was experienced in providing proper air-flow through the radiators.

There is general agreement that air cooling is preferable for "rotary-wing" piston engines, and that assistance from ejector exhausts should be employed wherever possible. The engine proposed by Capt. Forsyth, for example, would have vertical cylinder finning (so allowing the cylinders to be close together, saving engine length and weight) enclosed in a duct admitting air at the base of each "pot" and employing ejector exhausts to induce a high rate of cooling flow. Oil coolers would also be connected to an ejector-exhaust system. Altogether, such an arrangement appears very attractive on paper, and should certainly reduce the proportion of engine power wasted in driving a cooling fan—currently about six per cent.

It is not proposed to enter into an analysis of the merits of the various possible multi-rotor configurations. Suffice to say that, having developed a good rotor, it is a logical step to employ two identical rotors on a larger aircraft. If both rotors are driven by a single engine, as in all the Piasecki machines now in service, the most convenient layout is a rear-mounted motor behind the cabin, driving a common high-speed shaft linking the gearboxes under each rotor. The rotors thus remain mechanically linked—as is essential, of course, if their blades intermesh—yet can be freed from the engine for autorotation.

The Bristol 173, however, is a twin-engined machine, and in this case it is possible to provide twin-engined safety by making it possible to de-clutch either engine and proceed with the remaining power unit driving both rotors. This provision makes it impossible to dispense with the high-speed rotor-connecting shaft which, to the possible detriment of noise and vibration levels, passes along the centre of the fuselage roof.

The employment of two lifting rotors obviates the necessity of a torque-correcting tail rotor, and so transfers the power absorbed by this rotor—usually some eight to ten per cent of the total—to the main rotors.

The direct converse of the multi-rotor arrangement is found in the Sikorsky S-56, developed as the HR2S to a U.S. Marine Corps' assault transport specification. Owing to its warlike purpose a number of unusual features are found in this great aircraft, among them a single, five-bladed main rotor which is capable of supporting the aircraft at full load even after one blade has been shot away. The rotor is driven by two Pratt and Whitney R2800 Double Wasps mounted in nacelles on the ends of the stub wings (p. 298). Both engines drive high-speed horizontal shafts which pass down the side of the stub-wing spar to a gearbox under the rotor hub. Either engine can, of course, be declutched if necessary. A noteworthy feature of this helicopter is the liberal provision of intakes for cooling air, in the rotor pylon (for the gearbox), in the centre-section and nacelles (for the engines) and in the nose of each nacelle (probably for the generators). Such is the penalty of extended hovering flight, which is required of a military helicopter.

Although no details can be given of the actual engines fitted, it is known that they are de-rated to about 1,900 h.p., compared with at least 2,400 for fixed-wing R2800s. This may be partially due to the power loss in the transmission and in the provision of large cooling fans, but probably also reflects a revised rating system, in which the 1,900 h.p. maximum is available for periods of at least one hour. A very similar type of Double Wasp is employed on the anti-submarine Bell HSL-1, although this aircraft has the opposite layout—one engine and two rotors. Here, the engine is mounted in the centre of the fuselage, with the crankshaft horizontal. These two very important aircraft, both of which are being mass-produced, would certainly have merited a vertical-crankshaft Double Wasp, had such an engine been considered necessary.

Probably the best piston-engine installation actually in service is that of the Sikorsky S-55, which has a single engine mounted diagonally in the extreme nose.

So much for the piston engines; in spite of the fact that every helicopter in current service is so powered, it is widely held that the reciprocating engine has only a limited future. The power plant system most nearly resembling those used today is that in which the piston engine is simply replaced by a shaft-drive gas-turbine, without much modification to the transmission. The characteristics of turboprops differ considerably from those of piston engines, in almost every major parameter, but there is little doubt that a properly developed turbine is preferable in most installations.

Dealing first with the debit side of the balance-sheet, a gas-turbine still burns rather more (but not much more) fuel than does a piston engine of the same power. Overhaul lives are, at present, on the short side. First cost is possibly rather higher than that of an equivalent piston engine. And, if the engine is

ROTARY-WING POWER . . .

of the single-shaft layout, starting can be difficult, there is danger of overloading and stalling the engine-blading, and operation is best confined to a rather narrow power band.

On the credit side, the gas turbine can be developed to give far greater power than can a piston engine of comparable weight and bulk. For a really large rotor, of perhaps 90ft diameter and requiring 3,000 h.p., the installed weights of suitable piston and turbine engines might be of the order of 5,000 and 3,000 lb respectively. Admittedly, the turbine may be lengthy, and will certainly require more careful siting and ducting if pressure-losses are to be kept to a minimum.

One overwhelming advantage is the fact that a gas turbine requires no cooling system, even for extended hovering. Only an oil cooler is required, although the heat-release rate of this unit may be considerable, for the oil will have to cool the main gearbox, which may be transmitting some thousands of horse-power. It should be possible to maintain sufficient air flow through the oil cooler by employing an exhaust ejector, which could ventilate the engine compartment at the same time. Directly related to the small capacity of the oil system is a much reduced warm-up period; a turbine-driven helicopter can be airborne within about 30 seconds of a start from cold—a great operational asset.

Other important advantages of the gas turbine are its ability to run on inferior fuels, the reduction in noise and vibration transmitted from the engine compartment to the cabin, the compactness and low drag of an installed turbine, and the fact that such a power plant can be made to provide a ready source of compressed air for auxiliary power services.

But best of all is the fundamental type of drive obtained from a gas turbine. The turbine is essentially a high-speed engine and, by running the drive shafting as near as possible to engine speed, transmission weight can be reduced. (Nevertheless, even if shafting is run at higher speeds, a turbine will probably need more gearing-down than a piston engine; Raoul Hafner has said that, whereas the Bristol 173 currently has 12 gears, 22 would be needed on his company's new turbine-driven aircraft.) Again, it is likely that helicopter turbines will be capable of being continuously rated at a higher proportion of the maximum power than are present piston engines.

It was previously stated that the single-shaft gas turbine is not wholly suitable for helicopter propulsion owing to the shape of its power/torque/r.p.m. curve (Fig. 3). On the other hand, the free-turbine engine—the pattern developed by Bristols, in which the shaft-drive reduction gear is driven by a separate power turbine, mechanically independent of the rest of the engine—appears to be eminently suitable for helicopter propulsion. It is extremely "flexible" in its characteristics; it can be made to give useful power over a wide range of operating speeds; there is no apparent need for any form of clutch; and its torque characteristics are such that, although the rotor can be run at its optimum-efficiency r.p.m. for take-off and climb, the same power can be absorbed at much higher r.p.m. for high-speed cruising, particularly at altitude.

Fig. 4. The Lycoming O-435-4 flat-six piston engine installed in a Kaman HTK-1. The cooling fan is evident; the main rotor drive is at the front.

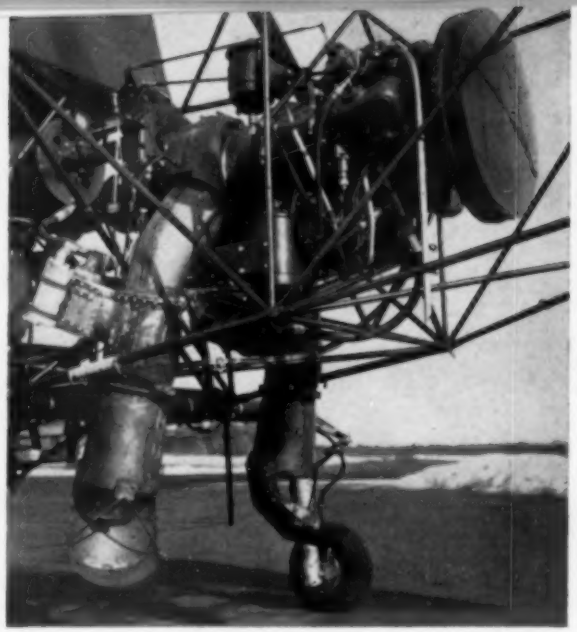


Fig. 5. A Boeing T50-BO-2 (Model 502) experimentally installed in the Kaman K-5 (K-225 modified). The exhaust stacks now point skyward.

Another immense advantage is the fact that, in the free-turbine engine, overloading is not the handicap that it is to the single-shaft engine; furthermore, sudden fluctuations in rotor torque or speed are not transmitted immediately to the engine, so that the turbine/compressor assembly should be able to run smoothly under all conditions, without danger of stalling. Starting a rotor-driven free-turbine is quite straightforward, and control is likely to be very simple. It is also expected that it will prove practicable to couple two, or more, such engines together.

At present many manufacturers are developing free-turbine helicopter engines. A special committee of the American Society of Automotive Engineers is even now attempting to find the general consensus of opinion on such problems as: "What is the optimum envelope of bulk . . . and, if accessories have to project beyond the circumscribed circle, should they compromise height or width?; should the drive be on the inlet or exhaust end of the turbine?; would you prefer a turbine to be supplied with a reduction gear? . . . if so, what output speed?; if the majority prefer an offset spur reduction, should the offset be to the top, to the bottom or lateral?; do you anticipate the need for bleed air . . . even if the power . . . could be taken more efficiently, from a weight standpoint, as shaft power?; what shape of inlet . . . and exhaust?; what type of accessory mounting pads, if any?; where should the engine-mounting pads be sited?" —and so on.

The first company to study a real helicopter turbine was Solar, whose T-400 was of reverse-flow layout. Eventually they decided against this layout which, although making the engine compact, caused about two per cent flow loss in the scrolls, which themselves contributed "excessive weight." Solar engineers presented a paper last year at which the following conclusions were stated, regarding helicopter turbines: axial compressors were preferable; so was an annular combustion chamber; the optimum turbine configuration appeared to be two stages to drive the compressor and one "free" stage to drive the rotor gearbox; a turbine capable of taking the place of a piston engine in an existing aircraft needed a planetary reduction gear, whereas a turbine designed for a wholly new helicopter with high-speed shafting could manage on a simple spur gear; for a given power output, reduction-gear weight should be less than that for a fixed-wing turboprop reduction gear, owing to the heavy gyroscopic and thrust loads imposed on the latter; anti-friction bearings were desirable; and no accessories, except possibly an oil and scavenge pump, would be mounted on the main gearbox, although an engine-accessory drive would be taken from the gas-producer part of the engine. No mention was made of airframe accessories, which presumably would be driven by air-bleed turbines; we would have expected such units to be driven by the rotor gearbox, where they would remain operative after engine failure.

Two photographs on this page show the flat-six piston engine of a Kaman HTK-1 (Fig. 4) and, for comparison, the installation of a Boeing 502 free-turbine engine in an experimental Kaman K-225 (Fig. 5). The Boeing 502-2 was rated at 210 s.h.p., about 29 per cent less than the Lycoming flat-six (Fig. 4) originally fitted. But, operating at 2,500 lb all-up, the turbine-driven machine had 693 lb more useful load, double the service ceiling, half the maintenance (inspections at 50-hr, as opposed to 25-hr, intervals), and an initial climb from vertical take-off of 700 ft/min compared with 440. The Boeing 502 weighed, installed, 13 per

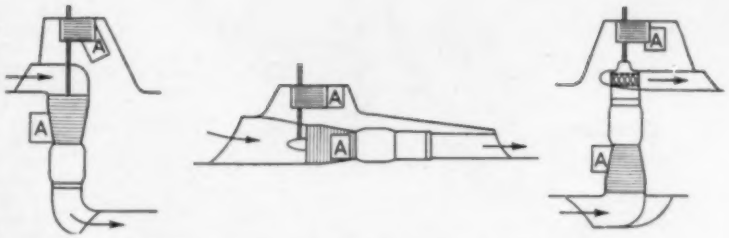


Fig. 6. Some possible arrangements for helicopter gas turbines. The left-hand engine is a free-turbine, with the drive take-off at the inlet end; the centre unit has a right-angle take-off near the intake, while the right-hand engine has a free turbine driving a shaft protruding from the exhaust end, so that the intake is under the belly of the aircraft. Letter A denotes the position of possible accessory-drive boxes.

cent of the gross weight, compared with 25 per cent for the piston engine. Specific fuel consumption, based on lb/rotor h.p./hr, approximated to 1.15, compared with 0.75 for the piston engine; nevertheless the Boeing-powered helicopter had an advantage up to a duration of four hours. Much other information of a like nature has been made available by the Kaman company.

Another set of most interesting figures are beginning to flow from Sikorsky, who are extremely pleased with their conversion of an S-52 helicopter from a Franklin 0-245 flat-six (245 h.p., 372 lb) to a Turboméca Artouste single-shaft turbine (400 h.p., 230 lb). Ralph P. Alex, the engineer in charge of this project, has said that, if performance is based on normal maximum power, and "take-off" is reserved for hot-weather or emergency operation, then the single-shaft engine presents no problems. Further, the control system—a simple flyball governor which reacts "violently" to minute r.p.m. changes—provides a precise control, which is so damped as not to over- or under-shoot. Alex reports "we get the control system we've been hunting for 12 years. It's easier to fly the ship because . . . we eliminate all co-ordination between throttle and collective pitch. The pilot just touches the throttle once to start the engine and engage the rotor . . . and doesn't touch it again until he's through." Owing to the high rotational inertia of the engine, the single governor maintains a drive-speed constant within two per cent at all power ratings.

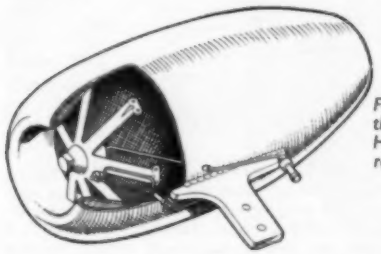


Fig. 7. A simple ramjet, that for the Hiller HJ-1 Hornet. This unit is referred to in col. 2 on this page.

Returning to the free-turbine engine, it is clear that, since the only connection between the gas-producing section and the power turbine is a flow of hot gas, there is no large penalty in mounting the gas producer and power turbines remote from each other, joined by a gas pipe. As the latter will not have to withstand worse conditions than about 150 lb/sq in at 600 deg C, the weight per foot run should be acceptable.

Alternatively, it is possible to have an air-compressor in the fuselage—either a gas-turbine compressor bleed or a separate unit driven by a piston engine—supplying cold air to a combustion chamber and turbine geared to the rotor.

All helicopter designers are convinced that there is an upper limit to rotor size somewhere near 100ft diameter, and many designers feel that, for such large sizes at least, a hub drive is inefficient. The alternative is the use of some form of reaction jet at the tip of each blade, which automatically obviates the need for any form of torque-correcting rotor, and offers other advantages such as the possible elimination of drag hinges and simplification of the rotor head.

The simplest systems employ rotor blades of conventional section and construction, but carrying a rocket, pulsejet, pressure jet, or ramjet at the tip. Even tip turbojets have been suggested. Some strengthening of the blade may, of course, be required to accommodate the increased tensile stress caused by the extra weight on the tip.

A rocket-driven rotor can look very attractive for some purposes—on paper, at least The pilot attaches small solid-fuel rockets to the tip of each blade and starts an engine driving a forward-propulsive airscrew. The rockets are fired electrically and the aircraft takes off vertically; once at a suitable height, the pitch of the airscrew is increased so that the rotor can autorotate as soon as the rockets are spent—after perhaps 20 seconds. The rockets are then jettisoned, leaving a "clean" rotor.

The pulsejet can also be started with the rotor at rest, and has a moderate fuel consumption (about 4 to 6 lb/h.p./hr). Many companies, including Fairey and Saunders-Roe in this country, have experimented with such units; while they are undeniably light and simple, it is agreed that noise, cooling and general inflexibility pose grave problems, and the writer knows of no present pulsejet with a valve life greater than about 50 hours.

The ramjet is used in numerous American helicopters, and offers the simplest form of air-breathing propulsion possible. But it is also excessively noisy, and cannot start from rest; furthermore, it cannot show an acceptable efficiency under the speed limitations of present rotors—say 700 ft/sec tip speed. Perhaps, in about five years time, it may come into its own on really advanced supersonic rotors. At present it is only of interest for very short-range "personal" helicopters of the "stick and string" type. Such a machine is the Hiller HJ-1 which has a tail rotor for yaw control, driven by a small piston engine. Another factor is that both pulsejet and ramjet helicopters have poor autorotative characteristics, owing to the drag of the units on the blade tips.

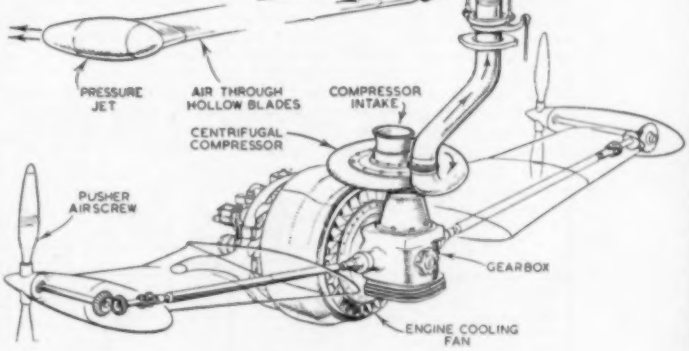
The pressure jet obtains compressed-air or gas power from a unit mounted in the fuselage. Pioneer work on such devices has been undertaken by M. Morain, Herr Doblhoff and Capt. Forsyth of Faireys, and the latter company are basing impressive developments on this means of propulsion. Although no details can be given, it is known that Faireys have had a test-rig running for a year or more, with a 60ft rotor fed by air bled from two Rolls-Royce Darts. Fairey experiments show, quoting Forsyth, "that by carefully controlling the compression ratio and mixture strength [of the gas producer] we can get down to 2.4 lb/hr/lb thrust where the rotor h.p. equals the engine b.h.p., and 1.8 where the r.h.p. equals 0.75 engine b.h.p. Fuel/air ratio can vary between 15 or 20 to one at full power, and be as low as 50:1 under certain flight conditions."

The richer ratio is obtained by burning additional fuel in the tip-jet unit, and the latter can consequently be made much smaller than can a ramjet or pulsejet of equal power. Thus, the Hiller Hornet ramjet unit (Fig. 7) gives 32 h.p. for a diameter and length of 7in and 8in, and a weight of 10 lb; but a Fairey pressure jet 7.7in diameter, 24in long and weighing 32 lb will develop 500 h.p. Such a unit was exhibited at the last S.B.A.C. show. It should be acceptably quiet and, since the gas temperature passing down the blades is under 180 deg C, no heat-dissipation problems are expected.

Similar advantages are claimed for the Percival P.74, which is powered by a "Napier high-efficiency, low-pressure gas system." The gas is presumably produced by a fuselage-mounted Napier Oryx, and passes to pressure-jets at the tips of the three rotor blades. As quietness is claimed it may be assumed that there is no tip-burning.

A pressure-jet rotor has now been developed for the Fairey Gyrodyne, in which the original Alvis Leonides piston engine drives a centrifugal compressor at crankshaft speed. Bevel gears provide take-off shafts for outboard pusher propellers (Fig. 8).

Fig. 8. The layout of the power unit of the Fairey Jet Gyrodyne research aircraft. Originally, this machine had a mechanical rotor drive.



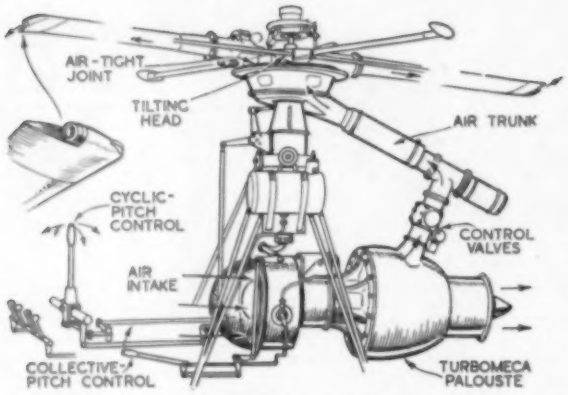


Fig. 9. The propulsion system of the latest SO.1220 Djinn, with compressed-air jets at the blade tips.

ROTARY-WING POWER . . .

The two propellers are driven the whole time, in the constant-speed régime, and their pitch can be hydraulically governed differentially to provide yawing control. The drive to the compressor incorporates a fluid clutch. This aircraft has now completed a considerable amount of experimental running and it is serving as a development prototype for such advanced projects as the Rotodyne (p. 294).

One such project has the following features: in the fuselage are two complete gas turbines, driving air compressors *via* starting clutches or free turbines. These feed air to (a) the rotor head, and thence through the hollow blades to tip jets, and (b) to the plenum chambers of two outboard units, each of which consists of combustion chambers, a turbine, a reduction gear and an airscrew (i.e., a turboprop *sans* compressor). The air ducts from the main compressors are all fitted with throttles, so that the airflow to any selected unit can be individually controlled.

At take-off, both engines are running, most of the air going to the rotor to provide lift, and a little being used to provide airscrew power for yaw control. The change-over to full forward flight is made by gradually transferring air power from the rotor to the airscrews, until the rotor is wholly, or partially, autorotating. A fixed wing is also employed to help to unload the rotor and increase air-speed; this is a potent means of increasing helicopter speed, but is rather outside the scope of this article.

To date, the most successful pressure-jet helicopter has been the French SO.1220 Djinn (Fig. 9). Originally conceived as a ramjet-powered machine, the Djinn was redesigned to take a Turboméca Palouste gas-generator (virtually a turbojet with an oversize compressor in which the excess air is not used as a jet, as in the by-pass engine, but tapped off along a duct). Many of the problems of tip-drive had already been solved by S.N.C.A.S.O. with the Ariel III, and this experience was put to good use, although the Ariel's tip combustion chambers were deleted.

With this revised system, the rotor receives about 50 per cent less power than it would were extra fuel burnt at the tips, but the overall specific consumption is at least as good. The chief advantage is, however, greatly reduced complexity and easier control. As the drawing shows, the small jet nozzles scarcely affect the aerodynamic properties of the rotor at all.

The air-shaft joining the Djinn's engine and rotor acts as a perfect fluid drive, and enables the pilot to select the optimum rotor r.p.m. for any altitude, irrespective of engine speed. The Djinn has a useful load equal to the empty weight—a remarkable fact for such an aircraft—and costs less than one-half as much as hub-drive aircraft. Stability is high, there is no anti-torque rotor (only a small rudder in the Palouste efflux), and the rotor can be passed into the autorotative state exceptionally easily. The Djinn has been followed by the Farfadet, which has a fixed wing and a nose-mounted turboprop in an endeavour to increase speed.

A less-common type of rotor drive is that in which hot gas is bled directly from a turbojet and used as a propulsive jet at the blade tips. It can be expected that such an arrangement would permit some simplification and weight-saving, in comparison with more advanced systems involving auxiliary compressors; but designers are proving understandably hesitant about undertaking the development of a rotor blade which acts as a tunnel for a flow of gas at over 600 deg C. Fatigue problems are already bad enough in rotor blading, without introducing high-temperature difficulties.

Some amelioration of this problem could be achieved by mixing the turbine efflux with compressor-bleed air, which should also afford some reduction in specific consumption. On the other hand, the blade section is already stretched to its limit to accommodate the gas-pipe, and the required increase in rotor solidity might well prove excessive. The performance of a hot-gas jet is given in Fig. 10 together with comparative figures for a pressure-jet; these curves—all of which are due to R. H. Miller, Kaman's vice-president, engineering—are based on the following assumptions: (pressure jet) compressor efficiency, 83 per cent; s.f.c. of engine driving compressor, 0.60 lb/hr/h.p.; rotor tip speed, 600 ft/sec; duct loss, 0.10 atmosphere; rotor configuration, two blades with disc- and power-loadings of 4 lb/sq ft and 13 lb/h.p. The two latter figures are high. For the hot-gas jet the foregoing assumptions hold, where applicable, with the value of 1,500 deg F given for turbine inlet temperature.

Mr. Miller presented a comparative table for various types of helicopter power plant at the last Anglo-American Conference: we have taken the liberty of revising his figures somewhat—in the light of later developments—in the table on this page.

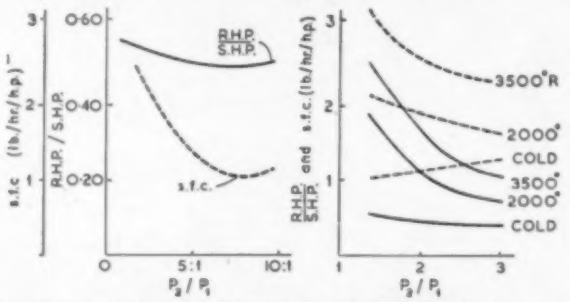


Fig. 10. Comparative curves for a hot-gas-jet rotor (left) and a pressure-jet rotor (right). In each case the full line is the ratio of available rotor power to required compressor or shaft power, while the broken line is the specific fuel consumption in lb/hr/rated h.p. Degrees R correspond to 460 + deg F. The horizontal axis is compressor or gas-generator pressure ratio. The assumptions made are listed in the text.

Briefly, the following appears to be the prospect for each type of rotary-wing aircraft: (1) *The short-range light liaison helicopter.* This may be expected to employ a small piston engine, or—if of a military character—tip-drive pulsejets. (2) *The naval or military assault transport or anti-submarine helicopter.* Free-turbine with hub drive. (3) *The medium transport.* Free-turbines with hub drive, in conjunction with fixed wings. (4) *The fast transport.* A single rotor and fixed wing, with forward propulsion by turboprops. Rotor drive by a gas system or—if a supersonic rotor—by tip ramjets. (5) *The "flying crane."* Tip-drive either by pulsejet or by pressure jets. The latter is more likely, with tip burning. (6) *The convertiplane.* This advanced cross between a fixed- and rotary-wing aircraft will probably be most efficient as a multi-turboprop aircraft, with the engines driving outsize airscrews-cum-rotors, and pivoted to a fixed wing of high-speed section. The airscrews should not have to be supersonic, even for a forward speed of 350 m.p.h.

These suggestions are no more than the opinion of the author; they are offered to emphasize the very great variety of propulsive systems now becoming available to the designer of rotary-wing aircraft. No doubt, some of these arrangements will be found to be much better than others, but it is unlikely that any company will suffer seriously through backing the wrong layout. Differences of opinion, however, are widespread; we know that several senior American designers view gas-shaft drives with scorn, while the proponents of these systems are convinced of their all-round superiority. It is therefore, most heartening to note that the Ministry of Supply has allocated money for the development of several advanced types of British rotary-wing machine—and other development contracts will certainly be placed when the companies concerned are ready.

It seems to indicate that, after an extremely slow start, Britain is going to become a leader in the rotary-wing field.

W.T.G.

Type of Power Plant	Installed Specific Weight (lb/h.p.)			Specific Fuel Cons. (lb/hr/h.p.)	Total Weight per horse-power for Endurances of			
	Eng.	Trmssn.	Total		1 hr	2 hr	3 hr	4 hr
Piston engine	2.00	0.70	2.70	0.48	3.18	3.66	4.14	4.62
Shaft-drive turbine ...	1.25	0.50	1.75	0.52	2.27	2.79	3.31	3.83
Hot-gas jet	2.00	—	2.00	1.25	3.25	4.50	5.75	7.00
Subsonic ramjet ...	0.30	—	0.30	5.00	5.30	10.30	15.30	20.30
Supersonic ramjet ...	0.02	—	0.02	2.50	2.52	5.02	7.52	10.02

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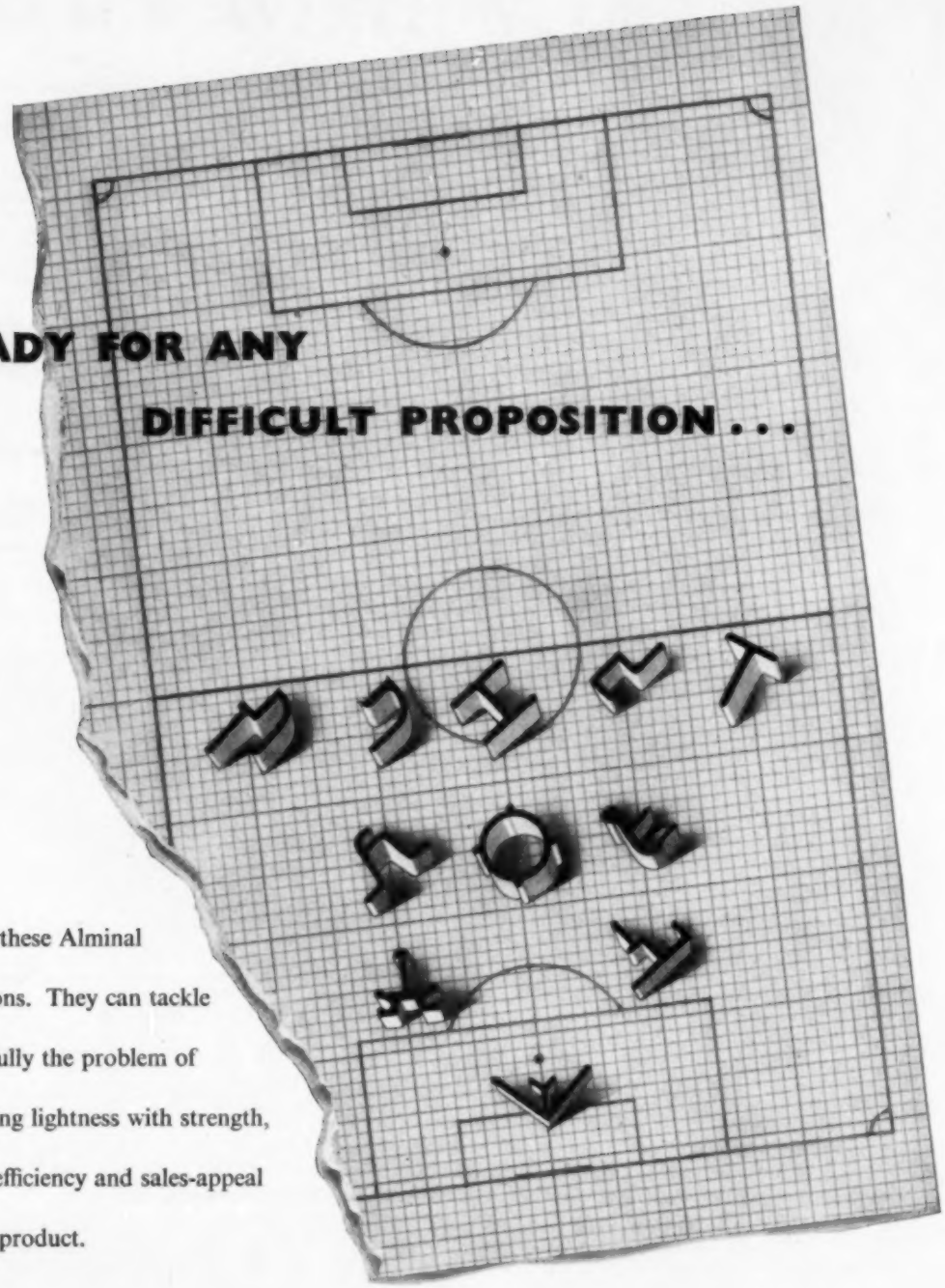

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A page from
THE ESSO HISTOIRE OF AERIAL LOCOMOTION
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BESNIER'S MACHINERY

IN 1678, in the French town of Sable, a locksmith named Besnier, tired of anticipating Yale, equipped himself with wings, and jumped off a stool. *Le Journal des Savants* of the period, which published the report, gives no hint of the met conditions at the time, but Besnier seems to have touched down successfully, for we next hear of him jumping off a table. Encouraged by these adventures, and by a flight through a moderately high window, the intrepid craftsman went upstairs and leaped out of the attic, "whence he flew over the neighbouring houses". The journal adds that Besnier didn't claim to stay in the air very long—and it will be seen that even for short flights he had to tie his hat on. He affirmed, however, that taking off from a moderately elevated point, he could easily fly over a river of considerable breadth.

Besnier's first wings were bought at a fair by a showman who later achieved some fame as a flying acrobat. A carved wooden panel commemorating the achievements of this great designer was for many years used as the sign of a village inn. The proprietor made a fortune : Besnier, unfortunately, did not.

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SERVICE AVIATION

Royal Air Force and Fleet Air Arm News

R.Aux.A.F. Appointment

IT is announced that the Queen has approved the appointment of the Rt. Rev. Dr. H. W. Bradfield, the Lord Bishop of Bath and Wells, as Honorary Air Commodore of No. 3507 (County of Somerset) Fighter Control Unit, R.Aux.A.F., with effect from February 25th.

No. 3507 F.C.U., one of the largest in the country, is commanded by W/C. G. C. Joyce. It is located at Rudloe Manor, Hawthorn, Wiltshire, with town headquarters at Cleveland House, Sidney Road, Bath.

This will not be Dr. Bradfield's first Service experience. He served in the 1914-18 war with both the City of London Yeomanry and the Army Cyclist Corps. He succeeds A. Cdre. E. Cadbury.

Service Pay Adjustments

NEW pay adjustments for the Services were detailed in a Government White Paper* published on March 2nd. Effective from April 1st, they are designed to give increased recognition of long service, skill and experience. Principally they entail basic pay increases, according to rank and length of service, of between 4s and 7s per day for officers and 2s and 4s per day for other ranks. In general, members of the Women's Services will receive three-quarters of the rates for men.

Basic increases as they apply to the R.A.F. will be 4s per day for flight lieutenants with not less than four years' service in that rank, 5s per day for squadron leaders, 6s per day for wing commanders and 7s per day for group captains and air commodores. Adjustments for medical, dental and other branch officers, are being made on a similar basis. Pay of other ranks is also to be adjusted. In addition to basic-pay increases, extra pay of 1s 6d per day will be introduced for technicians, N.C.O.s and warrant officers servicing aircraft and air equipment. Incremental pay for all ranks will be increased from 6d to 1s per day, and a new rank of master technician, with status and pay of a warrant officer, higher scale, will be created.

The present bounty scheme will be extended to provide £100 tax free for specially valuable men who continue their service, after 22 years, to the age of 55. A re-engagement bounty of £75, tax free, will be offered to airwomen from April 1st next.

National Service men's pay remains at its present level.

**Service Emoluments. Cmd. 9088. H.M. Stationery Office, price 6d.*

No. 24 Squadron

ON Thursday of last week, at its base at Abingdon, Oxfordshire, No. 24 (Commonwealth) Squadron was presented with its Sovereign's Standard; it is the first unit of Transport Command to be so honoured.

The reviewing officer was Air Marshal Sir Charles E. N. Guest, A.O.C-in-C. Transport Command; this was one of his final functions in that capacity, for next week he hands over the Command to A.V-M. G. R. Beamish. He was greeted by the Station Commander, G/C S. P. Hagger.

After the Commander-in-Chief had inspected the squadron, drawn up in three flights against a background of Commonwealth flags, the Standard was consecrated by the Rev. F. W. Cocks, Assistant Chaplain-in-Chief. The familiar words lost nothing of their significance . . . "to consecrate this Standard, the solemn symbol of our loyalty, and with it ourselves, our service, our life. May this Standard never be unfurled save in the cause of justice, righteousness and truth." The service over, Sir Charles made the presentation and addressed the parade. He quoted from the squadron's history, reminding his audience that No. 24 in the 1914-18 war was the first true fighter squadron, and in the last war, as the unit employed on the transport of high officials, accepted the responsibility of many difficult and hazardous operations.

In this latter connection the squadron received a message from the Prime Minister which read:

"The mark of Her Majesty's favour which No. 24 (Commonwealth) Squadron receives this day must bring deep satisfaction to the Squadron and its friends. I have known the Squadron these many years and have had much kindness and service from its members. Its wings have carried me far and always with a happy outcome. May it continue to prosper in its service to the Royal Air Force and the Commonwealth.

WINSTON S. CHURCHILL."

The presentation ceremony concluded with the Standard being marched to the ranks of the squadron and received with a general salute, a march past the saluting base in both slow and quick time, and the final advance in review order.

The drill, under the Commanding Officer, S/L. J. L. Kerr, was excellent. F/O. F. J. McDavitt of the Royal New Zealand Air Force, was the Standard Bearer and Sgts. R. E. Aindow, D. I. Smurthwaite and I. Gibson made up the Escort.

SECOND GENERATION: P/O. I. L. Whittle, son of Sir Frank Whittle, the gas-turbine pioneer, who is now doing his flying training at R.A.F. Station Cluntoe, Co. Tyrone. By a curious coincidence, his course will be the last to qualify for wings on piston-engined aircraft.

Reunions

AN all-ranks reunion of No. 157 Squadron will be held on Saturday, March 20th, at 7.30 p.m., at the Blue Posts Tavern, 12, Kingly Street, Regent Street, London, W1. Free beer and buffet. Particulars from R. J. Coombs, 39, Cambridge Mansions, Cambridge Road, S.W.11.

SCOTTISH REVELRY: At No. 603 (City of Edinburgh) Squadron's Annual Ball held in Edinburgh on February 25th. Left to right: F/L. W. B. Macgregor, No. 602 (City of Glasgow) Squadron; G/C. J. C. Sisson, A.O.A. No. 12 Group; A. Cdre. C. G. Lott, Sector Commander; Miss Doris Millar; and S/L. R. A. Schofield, C.O. of No. 603 Squadron.

CORRESPONDENCE

The Editor of "Flight" does not hold himself responsible for the views expressed by correspondents in these columns; the names and addresses of the writers, not necessarily for publication, must in all cases accompany letters.

Ode to the Aircraft Carrier

I BEG to draw your attention to certain reactions to Earl Mountbatten's speech at Edinburgh, reported in *Flight* on January 29th, under the title of "Earl Mountbatten on Carriers":—

The Noble Earl has told his view
Of Naval ships and carriers too.
Of ships he had not much to say
But the latter are just the thing today.

The carrier is like a fair-sized town
With terraced messdecks up and down
In which a thousand men or more
May live and work and sleep and snore.

This town has all the usual stuff
Like telephones and church and duff,
Like fire-brigades and restaurants
And garages and charabancs.

But all these things this ship can boast
Enable it to act as host
At international events
In near and farther continents.

The Noble Earl is always right,
Our ships can do far more than fight.
But he could give more time to say
"The Fleet Air Arm's the thing today."

And all the time he must admit
That, though the carrier is fit
To save at earthquakes, fire and cold,
It's job's to fly, so I've been told.

Beaconsfield, Bucks. NOVICE.

Words and Meanings

I MUST applaud the sentiment expressed in your leading article, "High-speed Terminology" (February 19th). Much of the damage to the English language, technical and non-technical, is done in America and is thereafter sedulously aped by the more shallow-minded journalists over here. It is the American fashion never to use one word where half a dozen or so will do; and, when America adopts anything of British origin, to rename it so that it at least looks as though it could have been invented in America. A recent example of that sort of thing is the American use of the term "canted deck" where we use "angled deck." A canted deck, in my interpretation, is one with a list to one side or the other.

As for the various "sonics," I don't see why we couldn't adopt some terminology like bisonic for Mach 2 plus, trisonic for Mach 3 plus, quadrisonic, and so on.

Incidentally, what of the use of the appalling word "hoverplane" by the self-styled "popular" Press to describe a helicopter? An aircraft whose flight capabilities were confined to hovering would be no more than an expensive mechanical substitute for a kite-balloon!

Birmingham, 32. J. M. BRUCE.

Sopwith Designations

FURTHER to the most interesting correspondence on Sopwith types, I can add one or two items to Mr. Peter Brooks's list of type designations:—

1A.2 and 1B.2: Designations, used in the French Service at least, to denote "artillerie" and bomber versions of the Sopwith 1½-strutter.

Variations on these designations appear against civil-registered examples in the early nineteen-twenties, as Sopwith 1, Sopwith A.2, Sopwith 2A.2. Manufacturer's serial numbers for some of these are:

F-ABDR	Sopwith	A.2	No.	5249	F-ABDV	Sopwith	1	No.	393
F-ABFB	"	A.2	"	3282	F-ABFC	"	A.2	"	3124
F-ABFD	"	A.2	"	522	F-AGEV	"	1	"	270
F-AIAG	"	1	"	3250	F-AIAH	"	1	"	1529
F-AIAJ	"	1	"	2292	F-AIAX	"	1	"	3249
F-AEGU	"	1A.2	"	2908	F-AEGH	"	A.2	"	7300
F-ABFN	"	A.2	"	7218	F-AHCP	"	B.1	"	5078
F-AIEC	"	1A.2	"	3533	F-ABCZ	"	1B.2	"	6032

Desford, Leicester. DONALD A. S. MCKAY.

IN BRIEF

Mr. J. Wotherspoon (14 East Main Street, Broxburn, West Lothian, Scotland), associate editor of *The Airpost Journal* and *The Air Log* (U.S.A.), is trying to secure a cover carried on the first night helicopter airmail service, from Peterborough to Norwich, on October 17th, 1949; he would be grateful if readers could provide information that would assist his quest.

THE INDUSTRY

Hydrogen Thyratrons for Radar

THE communications and industrial valve department of Mullard, Ltd. (Century House, Shaftesbury Avenue, London, W.C.) announce that two hydrogen thyratrons, types XH8-090/4C35 and XH16-200/5C22, are now available. These valves are stated to be particularly suitable for airborne, ground and navigational radar installations employing high-peak, short-duration pulse powers where maximum economy of space and weight is essential. The two types are, respectively, plug-in replacements for American types 4C35 and 5C22. They are also used in Service equipment under the designations CV1787 and CV2520. Both valves function with a heater voltage of 6.3 V. Operating temperature range is wide (−50 deg C to 90 deg C).

Nylon under Load

SOME hundreds of different components moulded in and/or machined from Akulon—a polyamide, or nylon, plastics material—were displayed at a private exhibition held recently in London by the Hercules Power Co., Ltd. Included among them were representative gear pinions of various types and sizes, and for such applications the material is stated to be particularly suitable. It has high tensile- and impact-strength, low specific gravity and a low modulus of elasticity and thus offers useful shock-absorbing properties, high resistance to wear, and silent running. It is claimed that such gears, correctly designed, will usually outlive those made of metal or other materials.

One interesting application shown at the exhibition was the protection of steel cable, conferred by coating the cable with a special grade of Akulon by an extrusion process. The coating is stated to be resistant to ester lubricants.

Akulon is manufactured by the AKU company of Arnhem, Holland. The Hercules Powder Co. are the distributors in this country, and an unusually comprehensive range of technical literature is obtainable from their offices at 140 Park Lane, London, W.1.

English Electric Bradford Appointment

APPOINTED manager of the aircraft equipment division of the English Electric Co., Ltd., at Bradford is Mr. P. J. Daglish, B.Sc., A.M.I.E.E. Mr. Daglish joined the company after war service as an engineer officer in the Royal Navy. In 1950 he was deputy chief development engineer at Stafford and in 1951 took charge of co-ordination of development between the various product groups. In this capacity, he was closely associated with aircraft equipment production.

Mr. P. J. Daglish.

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The C.I. tally counter, with finger ring.

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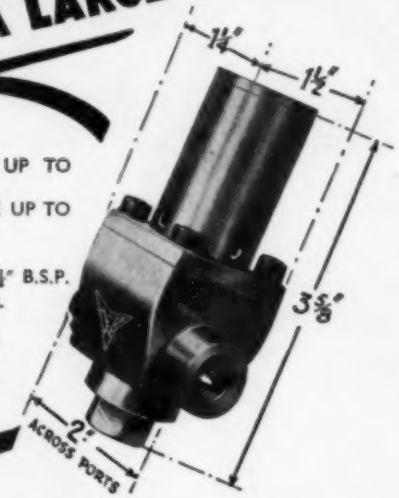

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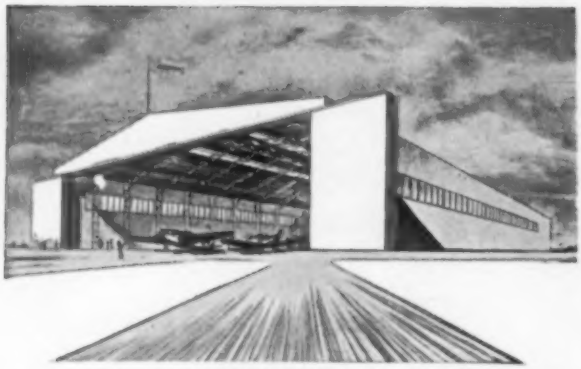

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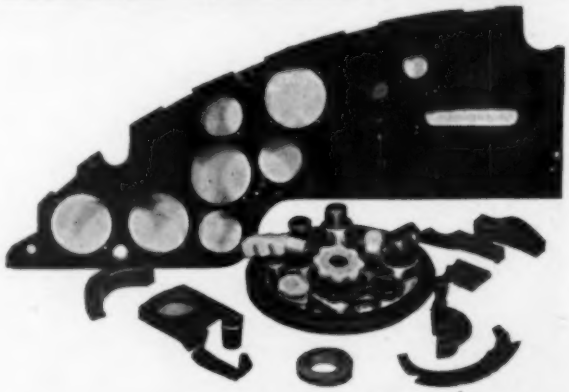

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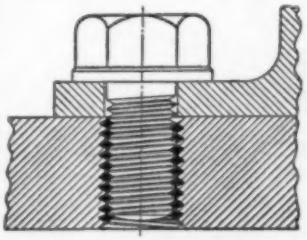

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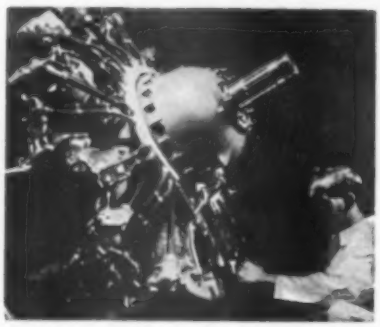

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PUBLIC ANNOUNCEMENTS

AIR TRANSPORT ADVISORY COUNCIL

THE Air Transport Advisory Council give notice that they have received the undermentioned applications to operate scheduled air services:—

Application No. 193/1. From Skyways, Ltd., of 7 Berkeley Street, London W.1. For limited traffic rights for the carriage of up to 10 passengers on each service between London and Malta on their Colonial Coach service on the route London (Stansted)-Malta-Nicosia which has been approved so far without traffic rights between London and Malta by the Minister of Transport and Civil Aviation for the period up to October 26th, 1955.

Application No. 216/1. From B.K.S. Air Transport, Ltd., of Dorset House, Old Burlington Street, London W.1, for a seasonal U.K. Internal service with Dakota aircraft for the carriage of passengers, supplementary freight and mail between Newcastle (Woolsington) and/or West Hartlepool (Greatham) and Bembridge, Isle of Wight at a frequency of one to three return services weekly during the season April to September inclusive, for a seven year period from April 1st, 1954. The Company asks that this service, if approved, should take the place of the Inclusive Tour service (Application No. 216) which they have been approved by the Minister of Transport and Civil Aviation to operate during the summer of 1954 on the same route.

THESE applications will be considered by the Council under the Terms of Reference issued to them by the Minister of Civil Aviation on July 30th, 1952. Any representations or objections with regard to these applications must be made in writing, stating the reasons, and must reach the Council within 14 days of the date of this advertisement, addressed to the Secretary, Air Transport Advisory Council, 9 Buckingham Gate, London S.W.1, from whom further details of the applications may be obtained. When an objection is made to an application by another air transport company on the grounds that they are applying to operate the route or part of the route in question, their application, if not already submitted to the Council, should reach them within the period allowed for the making of representations or objections. [1748

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Vacancies for Radio Officers

Central African Airways

1 **Central African Airways Corporation, Salisbury, Southern Rhodesia,** invite applications from preferably unmarried radio officers for employment under the following conditions:—

2 **QUALIFICATIONS**

Flight radio operator's licence.

3 **CONDITIONS OF EMPLOYMENT**

a Period of employment, which is non-pensionable, will be for a contract of one year, which may, by mutual agreement be extended for a further period.

b A basic salary of £820 per annum will be paid.

c Cost-of-living allowance will be paid. This is at present at the rate of 18 per cent. of the basic salary. This rate varies with the Consumer Index.

d The Corporation will provide life assurance benefits of four times the annual basic salary.

e A consolidated travelling and subsistence allowance is paid at the rate of £75 per annum and is not payable when the employee is sick or on leave.

f Vacation leave at the rate of 30 days per annum will be granted.

g Radio officers employed under these conditions will be required to join the Corporation's Medical Aid Society.

h Certain travel privileges will be available on the Corporation's regional and domestic routes.

i A gratuity equivalent to three months' basic salary will be paid on satisfactory completion of the one year contract. Gratuities will be paid at this rate for any mutually agreed extension to a contract.

4 Free air travel will be provided for successful applicants to Salisbury from London and return to London on completion of a contract. The employee's wife and children up to the age of 18 will be transported by air from London to Salisbury and return to London at 50 per cent. of the London/Salisbury "Tourist" fare. This amount may be repaid to the Corporation during the period of the contract.

5 Applications, giving full details of qualifications and experience must be made in writing by Air Mail addressed to the Operations Manager, C.A.A., P.O. Box 1979, Salisbury, Southern Rhodesia. Arrangements will then be made to interview candidates in London.

TUITION

THE COLLEGE OF AERONAUTICS

THE Board of Entry of the College invites applications from suitable candidates for the two-year course which begins in October, 1954, and ends in June, 1956.

CANDIDATES should be of graduate standard, although the possession of a degree is not essential; a good Higher National Certificate is an acceptable standard.

THE College, a post graduate institution, is devoted to the study of aeronautical science and engineering. The curriculum covers the five main subjects of aerodynamics, aircraft design, aircraft electrical engineering, aircraft propulsion and aircraft economics and production. Instruction in the first year is designed to provide students with a broad background of knowledge in all these subjects, with opportunity for limited specialization in two or three of them. In the second year students specialize more particularly, usually in one subject.

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STUDENTS who satisfactorily complete the course will receive the Diploma of the College.

FURTHER particulars and details of the procedure for application may be obtained from the Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks. [1622

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Vacancies for Pilots

Central African Airways

1 **Central African Airways Corporation, Salisbury, Southern Rhodesia,** invite applications from pilots for employment under the following conditions:—

2 **QUALIFICATIONS**

a Air line transport pilot's licence or

b Senior commercial pilot's licence or

c Commercial pilot's licence with instrument rating and minimum of 1,500 hours total flying.
Licence to be endorsed for Viking and/or Dakota type aircraft. Preference will be given to holders of licences endorsed for both types of aircraft.

3 **CONDITIONS OF EMPLOYMENT**

a Period of employment, which is non-pensionable, will be for a contract of two years, which may, by mutual agreement be extended for a further period.

b Basic salaries will be dependent upon qualifications and will be based upon experience within the following groups:
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c A cost-of-living allowance will be paid. This is at present at the rate of 18 per cent of the first £895 of the basic salary. This rate varies with the Consumer Index.

d The Corporation will provide life assurance benefits of four times the annual basic salary.

e A consolidated travelling and subsistence allowance is paid at the rate of £75 per annum and is not payable when the employee is sick or on leave.

f Vacation leave at the rate of 30 days per annum will be granted.

g Pilots employed under these conditions will be required to join the Corporation's Medical Aid Society.

h Certain travel privileges will be available on the Corporation's regional and domestic routes.

i A gratuity equivalent to six months' basic salary will be paid on satisfactory completion of the two-year contract. Gratuities will be paid at this rate for any mutually agreed extension to a contract.

4 Free air travel will be provided for successful applicants to Salisbury from London and return to London on completion of a contract. The employee's wife and children up to the age of 18 will be transported by air from London to Salisbury and return to London at 50 per cent of the London/Salisbury "Tourist" fare. This amount may be repaid to the Corporation during the period of the contract.

5 Applications, giving full details of qualifications and experience must be made in writing by Air Mail addressed to the Operations Manager, C.A.A., P.O. Box 1979, Salisbury, Southern Rhodesia. Arrangements will then be made to interview candidates in London.

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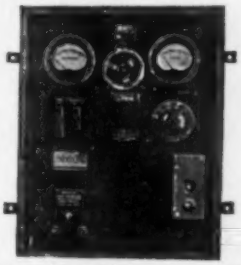

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